Did the Black Death cause economic development by 'inventing' fertility restriction?

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Abstract: The Black Death is claimed to have caused the European Marriage Pattern in England by raising pastoral wages and thus delaying female marriage. We show that this argument does not hold. There is no consensus that late female marriage emerged in rural England after the Black Death. Women wanting to do pastoral work in medieval England did not have to remain unmarried, so improved pastoral opportunities did not necessitate later marriage. Nor does the quantitative relationship between pastoralism and female marriage age in England provide support for this argument. Fertility restriction was not exogenously triggered by the Black Death.

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1. Introduction

The European Marriage Pattern (henceforth EMP) is the term used by historical demographers to describe the family system during the early modern period in most Scandinavian countries, England, the Low Countries, the German-speaking area, and northern France (Hajnal 1965, 1982). It involved women marrying late or not at all, nuclear-family households, and the circulation of young people between households as servants before marriage. Fertility consequently lay below the biological maximum and, because marriage involved forming a new household, responded to economic conditions.

Historical demographers have long speculated that the EMP calibrated population to resources, freeing economies from Malthusian limits (Wrigley and Schofield 1981; Laslett 1988). Fertility restriction is a necessary condition for sustained growth in many models of long-run economic development, and some recent contributions to the literature go further, arguing that the EMP caused European economic growth (Greif 2006; Voigtländer and Voth 2006; Greif and Tabellini 2010; De Moor and Van Zanden 2010; Foreman-Peck 2011; Foreman-Peck and Zhou 2018; for counter-arguments see Dennison and Ogilvie 2014, 2016).

Marriage and fertility decisions are influenced by economic considerations, so one objection to claiming a causal role for the EMP is that the EMP is an endogenous rather than an exogenous variable when explaining differences in living standards across pre-industrial economies. But if it could be shown that the EMP was the result of an exogenous shock, this objection would not apply. Voigtländer and Voth (2013) (henceforth VV) contend that the EMP was caused by the Black Death, an epidemic that killed upwards of one-third of the European population around 1350. The Black Death was clearly an exogenous shock, so if VV are correct in arguing that it caused the EMP, this means that the EMP can reasonably be taken as an exogenous influence on European growth, and hence an important cause of economic divergence between Europe and other continents.

The VV argument also has the attractive feature that, although based on evidence for England, it is in principle capable of explaining why the Black Death did not generate the EMP everywhere. VV argue that in England the Black Death increased demand for women's labour as servants in pastoral work instead of as wives in arable work, causing females to marry later, reducing fertility and increasing per capita income. However, VV's theoretical analysis shows that if, for example, total factor productivity in arable was high relative to that in pastoral agriculture, the Black Death was unlikely to lead to lower nuptiality and fertility.

VV argue that this is why the EMP failed to emerge after the Black Death in Southern Europe, Eastern Europe, or China.

VV therefore provide a unifying framework to explain pre-industrial demographic and economic divergence. Unfortunately, as this paper shows, their analysis cannot be sustained. As Section 2 explains, VV's argument is based on two key premises: first, that the EMP emerged in rural England immediately after the Black Death; and second, that women could work in pastoral agriculture only as servants, which required them to remain unmarried. However, Section 3 shows that these key premises are empirically incorrect. The debatable evidence on medieval English demography supports profoundly divergent conclusions about when the EMP developed, ranging from well before the Black Death to nearly 200 years after it. In so far as there is a consensus, it is that the EMP did not emerge in rural England soon after the Black Death. Furthermore, women in medieval England did not have to be unmarried to work in pastoral agriculture, so the crucial mechanism in VV's argument which generates lower fertility as a result of the shift to pastoral agriculture does not apply. VV contend that their argument is empirically supported by two positive causal relationships, one between pastoralism and the proportion of unmarried women in a cross-section of English counties in the later fourteenth century, the other between pastoralism and female marriage age in English counties several centuries later. However, Section 4 shows that the former relationship cannot be supported by the data VV use; that the latter relationship is not relevant to the central claim of VV's analysis, since it refers to female marriage age several hundred years after the Black Death; and that even if the latter relationship were relevant, the claim that it existed turns out to be incorrect. Section 5 concludes that the EMP in England was not exogenously triggered by a medieval epidemic and a consequent shift in factor proportions. This, we point out, has wider implications for the view that the EMP played a causal role in pre-industrial economic growth.

2. The VV argument

VV's argument is based on their view of the effects of the Black Death in England. A first component of this view is that the EMP did not exist before 1350 but emerged immediately afterwards, a claim we examine in the next section. A second component of the VV argument is based on the fact that after c. 1350, real wages for agricultural workers increased, as did pastoral relative to arable prices (Broadberry et al. 2015, pp. 60-1). Because

women have a comparative advantage in animal care, higher pastoral prices enabled women to earn higher wages in the pastoral sector.

It is important to recognize that higher female wages after the Black Death would not inevitably lead to later marriage and lower fertility. The substitution effect of higher wages is to delay marriage. But the income effect, if marriage and children are normal goods, is to make people marry earlier (Dennison and Ogilvie 2016). Furthermore, almost all European societies experienced the Black Death, but not all had the EMP. A convincing argument that the Black Death moved the English economy from a steady state with high fertility and low per capita incomes to one with lower fertility and higher per capita incomes has to explain why higher female wages in pastoral agriculture lowered fertility in England but not everywhere the Black Death occurred.

VV's theoretical model of the emergence of the EMP after the Black Death is able to do this. However, it is critically dependent on two questionable assumptions.[1] The first is that women's preferences between consumption and children involve a basic-needs level of consumption such that, for consumption below this level, increases in income do not lead to additional children but result entirely in additional consumption. This assumption ensures that higher pastoral sector wages initially result in a substantial drop in fertility. Fertility subsequently rises when income exceeds the basic-needs level. If women did not have a basic-needs level of consumption, the VV model would not generate EMP behaviour in response to increased pastoral wages. This assumption is also crucial in enabling VV's model to explain why the Black Death did not result in the emergence of the EMP everywhere. The centrality of this very specific assumption about preferences for generating EMP behaviour in the VV model raises a fundamental question about the general validity of the VV analysis, because any assumption about preferences is inherently untestable.

The second key assumption is that in order to work in the pastoral sector, women have to be servants and thus remain unmarried. This can be tested. It will fail to hold if peasant households can engage in pastoral agriculture, since women will then be able to work in the pastoral sector while being married and having children, even if servants working for landlords have to remain unmarried. It will also fail if women who are married can be employed in the pastoral sector, for example as wage-labourers, since then they will not have to avoid marriage to benefit from high pastoral earnings, even if peasant households do not engage in pastoral agriculture. In either case, the central link in VV's model – the trade-off

[1] For a detailed discussion of the VV model and these assumptions, see Appendix Section A1.

that women face between work in the pastoral sector and marriage – will break, and VV's account of how the Black Death caused the emergence of the EMP in England will not apply.

3. Are the key premises of the VV analysis consistent with the evidence?

3.1. When did the EMP emerge?

VV state that 'there is a consensus that EMP only became fully developed after the Black Death in 1348-1350' (VV, p. 2228). Unfortunately, no such consensus exists. The evidence is so ambiguous that historical demographers disagree fundamentally about when the EMP developed.[2]

The originator of the EMP concept was Hajnal, whose best guess in 1965 was that the EMP dated from 'somewhere about the sixteenth century' (Hajnal 1965, p. 134). By 1982, he had changed his mind, writing that behaviour consistent with the EMP 'can be traced back for perhaps four centuries prior to 1600' (Hajnal 1982, p. 477).

Hajnal based this conclusion on studies suggesting that thirteenth-century England manifested all the social practices associated with the EMP: life-cycle servanthood, little labour market segmentation by sex, legal entitlements enabling spinsters to work, female geographical mobility, marriage dependent on ability to form a new household, bilateral kinship, frequent remarriage, and narrow spousal age-gaps (Smith 1979, 1983, 1990a, 1990b; Hallam 1985; Goldberg 1991). Recent analyses provide further support for these findings (Bennett 2019a, 2019b).

So debatable is the evidence, however, that other medievalists contend that England had early marriage until after 1500 (Hatcher 1977, pp. 56-7; Razi 1980, pp. 50, 63, 137; Bailey 1996, pp. 2-9, 12-7; Mate 1998, pp. 29, 49; Mate 1999, pp. 59-60; Hatcher 2003, pp. 89-96; Benedictow 2012, pp. 11-23). In their view, for 150 years after the Black Death, mortality stayed so high that maintaining observed population size required early and universal marriage (Hatcher 1977, pp. 65-6; Hatcher 1986, pp. 21-2; Bailey 1996, p. 16; Hatcher 2003, pp. 100-4; Benedictow 2012, pp. 25-8). There is no evidence, these scholars argue, that female servants proliferated after 1350 or more women delayed marriage to stay in service, especially not in the countryside (Bailey 1996, pp. 7-8, 11-14, 17; Mate 1998, p. 45; Mate 1999, pp. 59-60). In large towns, some women delayed marriage until their mid-

[2] For further detail on the dating of the EMP, see Appendix Section A2.

twenties, but it cannot be shown that 'the *majority* of women, over the country at large, married late' (Mate 1999, p. 60). Short-term wage labour was so attractive compared to servanthood between 1350 and 1500 that 'women could and did combine early marriage with casual employment' (Bailey 1996, pp. 14).

A few scholars speculate that nuptiality changed around 1350 – but in contradictory directions. Hatcher and Razi hold that the Black Death increased wages and land availability, enabling couples to marry earlier (Hatcher 1977, pp. 56-7; Razi 1980, pp. 63, 131-8; Bailey 1996, p. 3). Early marriage was compatible with female employment because married women often worked as wage-labourers (Bailey 1996, pp. 13-4; Mate 1999, p. 59). In contrast, Goldberg argues that the Black Death created *urban* jobs for unmarried females, so marriage age rose in towns but stayed low in the countryside long after 1350 (Goldberg 2013, pp. 13-4, 24-6).

In sober fact, the data are inadequate to reach a definitive conclusion about when the EMP emerged. Reliable nuptiality statistics require parish registers and village censuses, which are unavailable for England before the 1540s (Dennison and Ogilvie 2016, p. 211). But no historical demographer argues that the EMP emerged in the *rural* economy immediately after the Black Death.

3.2. Life-cycle servanthood

A second problem arises with the assumptions VV make about servanthood. A defining characteristic of the EMP is widespread life-cycle servanthood by unmarried persons (Hajnal 1982, pp. 452-3, 470-6; Smith 1983, pp. 108-9, 113-5, 129-31; Laslett 1988, pp. 237-8; Poos 1991, pp. 183-206; Bailey 1996, pp. 5-6; Whittle 2017, p. 2; Bennett 2019a, 2019b). But VV assume that women could only work in pastoral agriculture as unmarried servants, which presumes that life-cycle servanthood was already fully formed in 1350. However, their source is Kussmaul (1981), whose evidence applies to 1538-1840. She conjectures in an appendix that life-cycle servanthood might have been widespread in the fifteenth century, but acknowledges this as speculative (Kussmaul 1981, Appendix 7). As discussed above, the data required to establish when life-cycle servanthood became pervasive in rural England are ambiguous, causing medievalists to reach widely divergent conclusions.

Whatever one's view on whether life-cycle servanthood was common in England before or after the Black Death, VV's analysis appears inconsistent. If life-cycle servanthood was so fully formed in 1350 that women had to be servants in order to do pastoral work, this

implies that the EMP predated the Black Death, and thus cannot have been caused by it. If the EMP emerged only after the Black Death, then life-cycle servanthood cannot have been widespread in 1350 and VV's assumption that women could only do pastoral work as unmarried servants is not tenable.

A further problem arises with the explanation VV give for why the EMP did not emerge everywhere after the Black Death. Their Corollary 2 in principle explains why the Black Death might have led to the emergence of the EMP in England but not in other European societies or in China (VV 2013, pp. 2250-2). But this explanation of why the EMP did not emerge in eastern Europe or China requires women in these countries to have been able to work in pastoral agriculture only as unmarried servants, since that is a key assumption of the VV model. However, eastern Europe and China did not have life-cycle servanthood (Hajnal 1982, pp. 461-2, 467, 473-4, Laslett 1983, pp. 526-7). Thus VV's model cannot explain why the EMP did not emerge in those societies.

3.3 Did English peasants engage in pastoral agriculture?

VV's model assumes that medieval peasant households did not engage in pastoral production, so peasant women had to delay marriage and work for landlords to profit from rising pastoral earnings. This is factually inaccurate. Medieval English peasants normally engaged in both arable and pastoral agriculture. They did this using land they held as tenants, using grazing rights on communal village pasture, and using pasturage on the post-harvest stubble of the village's open arable fields.[3]

Before the Black Death, the amount of land and livestock owned by the average peasant was relatively small, although in aggregate the peasants of a village could own hundreds or even thousands of sheep (Power 1941, p. 20; Dyer 1981, pp. 5, 30; Masschaele 1997, pp. 45-6; Dyer 2005, p. 78). Even at this low level, however, peasants produced arable and pastoral output for sale as well as consumption. Most peasants had to pay money rents, and a peasant family with sheep or cattle could seldom consume all the wool or hides, which were therefore sold on the market (Power 1941, p. 3).

The assumption that pastoral technology was available only to landlords is thus untenable. An alternative assumption which would yield similar results is that pastoral production required a minimum amount of land (VV 2013, fn. 27 p. 2238). If such a

[3] For further detail on peasants' pastoral production, see Appendix Section A3.

minimum scale existed, the evidence above shows it did not preclude pastoral production by numerous peasants. However, if peasants produced only a small share of pastoral output and landlords dominated the sector, VV's assumption of a minimum land requirement for pastoral production would be an acceptable simplification.

But there is overwhelming evidence that landlords did not dominate medieval pastoral production. Sheep were an extremely important part of the pastoral sector, and English peasants produced at least as much wool as large landowners. In the early fourteenth century, England exported about 30,000 sacks of wool in a typical year. Masschaele (1997, pp. 52-3) estimates that on average a maximum of 5,000 sacks were produced annually by ecclesiastical estates and 8,550 by lay estates. Over half of early-fourteenth-century English wool exports was thus produced by peasants. If domestic wool consumption comprised 25% of the quantity exported, then peasants produced almost 65% of total English wool (Masschaele 1997, pp. 52-3). Bridbury (1977, pp. 398-9) and Campbell (2000, pp. 158-9) provide somewhat different estimates, but also conclude that peasants produced a very substantial share of wool sold in medieval England. An individual peasant typically produced only a small quantity of pastoral output, but there were nearly a million peasant holdings and only 20,000 landlord demesnes.[4] Consequently, most of the cattle and pigs in late-thirteenth-century England were also kept by peasants (Dyer 2005, p. 89). Peasants operated on a small scale but were very numerous, so they contributed substantially to pastoral production even before 1350.

After the Black Death, labour costs rose, grain prices fell, and prices for meat, milk, cheese, and wool rose. Pastoral agriculture required only one-fifth of the labour per unit land needed for arable cultivation (Campbell 2000, p. 10). Peasants responded to these price signals by shifting from arable to pastoral production (Mate 1987, p. 525, Dyer 2005, pp. 129, 169). Peasant sheep, cattle, and pig holdings were much higher in the late fourteenth century and throughout the fifteenth than before the Black Death (Dyer 1981, p. 30).

One way peasants expanded pastoral production was by leasing pastures from landlords (Dyer 1981, pp. 4-5; Watkins 1989, p. 18). Such leases already occurred before 1350 but proliferated rapidly thereafter, and by c. 1450 most landlords had abandoned direct exploitation of their demesnes (Lomas 1978, pp. 339-40, 345, 352; Campbell 2000, pp. 3, 58-60; Dodds 2008, p. 77). This enabled many more peasants to get access to grazing and begin

[4] The basis for the estimate of 20,000 demesnes is explained in Section A3 of the Appendix.

raising livestock (Bailey 1989, pp. 257-8; Watkins 1989, p. 19; Campbell 1992, p. 113; Bailey 2007, pp. 220-1; Hare 2011, pp. 78-9, 101-5). Some peasants who leased land after the Black Death became large-scale producers, and thus can no longer be described as peasants, although they still leased rather than owned the land they worked. These lessees did not easily fit conventional social categories, and were described as 'farmers' by contemporaries (Dyer 2005, pp. 194-5, 207). But in one study of fifteenth-century Wiltshire, at least 39% of lessees originated as local customary tenants, i.e. peasants (Hare 2011, p. 101). Many demesnes were leased to multiple lessees, in which case peasants were invariably involved (Dyer 1981, pp. 4-5). Peasants thus also produced pastoral output as demesne lessees.

It might still be argued that, although peasants engaged in pastoral production, peasant wives only did arable work.[5] However, this idea would be hard to justify given women's higher productivity in pastoral than arable work, and the evidence does not support it. The sparse surviving evidence confirms unambiguously that medieval peasant wives were fully involved in the household's production in field and pasture (Power 1975, p. 71; Goldberg 1991, p. 82). Once married, women did very similar tasks to those they had performed as unmarried servants, in particular pastoral work (Goldberg 1991, p. 82; Mate 1999, p. 16). The peasant housewife bore the main responsibility for the daily care of the cows and sheep which many peasant households kept. Peasants' wives and daughters were expected to feed animals, help with calving and lambing, wean calves and lambs, milk cows and ewes, and make butter and cheese (Hilton 1975, 101-2; Hanawalt 1986a, p. 10; Goldberg 1991, p. 82; Goldberg 1992a, p. 110; Mate 1999, pp. 31-2; Bardsley 2007, pp. 63, 66). After the Black Death, the greater role of peasants in the pastoral sector made such activities even more important for peasant housewives (Mate 1999, pp. 31-2). Medieval coroners' reports show morning and noon peaks in peasant women's accidental deaths, resulting partly from women 'working with large animals' (Hanawalt 1986a, p. 8). In medieval and early modern peasant households, milking and dairying were exclusively female occupations (Whittle 2005, p. 69).

During the winter, peasant housewives cared for cows, sheep, and pigs when they were penned outside, sheltered in byres, or housed under the family roof. In other seasons, married peasant women took animals to pasture and herded them in the environs of the village (Hanawalt 1986a, p. 9; Bardsley 2007, p. 66). Medieval law-courts record peasant women being prosecuted 'for illegally trespassing with animals in the common field' (Graham 1992, p. 129). Landlords prosecuted peasant wives for animal-related offences, as in

[5] For further detail on peasant women's pastoral activities, see Appendix Section A4.

1331 when a married woman in Wiltshire was punished for taking her cow out of the landlord's pinfold (Müller 2013, p. 106-7). Pastoral production was sufficiently central to peasant housewives' responsibilities that in 1403 a Bothall woman bequeathed cows to two married women tending her in her final illness (Goldberg 1995, p. 179).

Married peasant women also carried out all the tasks involved in procuring and tending the household's sheep. Rural court records show the peasant housewife purchasing sheep and, along with the resident daughters, washing and shearing them (Goldberg 1992a, p. 110; Bardsley 2007, p. 66). Archival records describe peasant women 'clipping sheep in the pasture for their wool' (Hanawalt 1986a, p. 13).

The peasant housewife was the person mainly responsible for selling pastoral output – eggs, butter, cheese, yarn – in local markets and towns (Goldberg 1991, p. 82; Dyer 2005, p. 28, 89). Married peasant women had individual control over the money they earned by selling pastoral products (Hanawalt 1986a, pp. 15-6).

A woman who married a peasant did not, therefore, cease to do pastoral work. She could benefit from the post-1350 shift to pastoral agriculture by working with the family's own livestock. These empirical findings invalidate a central assumption of the VV model.

3.4 Did married women work for landlords?

VV's model assumes that women could only work for landlords as unmarried servants. This ignores the fact that the medieval agricultural labour force consisted not just of unmarried servants working for landlords and peasant families working for themselves, but also of independent labourers, including married women.[6] In the late fourteenth century, a large manor would employ four to ten unmarried servants, but one to two dozen labourers (Dyer 2005, p. 229). Labourers were recruited from poor peasant households and included married females (Middleton 1979, pp. 159-62; Hanawalt 1986a, p. 11; Smith 1990b, p. 53; Bardsley 2007, p. 63). Consequently, the work profile of women married to wage-earning men may not have been 'dissimilar from that of many single women' (Goldberg 1986a, p. 34).

After 1350, rising wages pulled wives previously doing unpaid household work into wage-earning employment (Dyer 2005, pp. 222-3). The Black Death triggered a shift from servanthood by unmarried individuals to wage-labouring by married couples. Labour scarcity

[6] For further detail, see Appendix Section A5.

meant workers could get steady work as higher-wage labourers, reducing the attraction of low-wage servanthood contracts whose main advantage was security (Bailey 1996, pp. 13-4). Humphries and Weisdorf (2015, pp. 417-23) show that for at least 150 years after the Black Death, day-wages earned by female labourers were substantially higher than the daily remuneration implied by annual contracts for female servants, possibly because servants were more vulnerable to legal wage ceilings. The daily nominal remuneration implied by annual servanthood contracts hardly changed from 1350 to 1500. The price level rose immediately after 1350, but stabilized from the later fourteenth century on (Broadberry et al. 2015, p. 191). Consequently, the Black Death did not increase female servants' wages in nominal terms and may even have reduced them in real terms. The higher female labourers' wages meant that from 1350 to 1500 a woman needed to work casually for only about 100 days a year to achieve the same earnings as a female servant from an annual contract.

Females – including married women – certainly made up a non-trivial proportion of English labourers after the Black Death. In Essex in 1352, over 15% of the 1,559 female labourers prosecuted for charging wages above the legal ceilings were certainly married (Poos 1991, p. 226). On one Essex demesne in 1483-4, women provided approximately one-third of all person-days worked by labourers; six of the sixteen named female labourers were recorded as married (Poos 1991, pp. 214, 217). On one Cheshire estate in 1498-1520, almost one-third of the 45 female day-labourers were married (Youngs 1999, pp. 157). Married women enjoyed good access to labouring jobs because they got employment via husbands and were exempt from socio-legal pressures to become servants (Youngs 1999, pp. 157-8; Humphries and Weisdorf 2015, pp. 411-2). Married female labourers performed the pastoral tasks normal for maidservants and peasant housewives, as on one Essex estate in 1483-4 where a married woman was paid to milk cows (Poos 1991, p. 217). Sparse documentation means that most descriptions of the precise work of female labourers date from after c. 1480, but there is no reason the many married female labourers recorded before that date should not also have done pastoral tasks, given the evidence that housewives did pastoral work on the peasant holding.

Married women also did other pastoral work for landlords. One thirteenth-century Lancashire estate hired married vaccary keepers who organized livestock care using their wives, offspring, and hired herdsmen. The wives and daughters were responsible for milking, butter-churning, cheese-making, and marketing. When the vaccary keepers moved the herds seasonally, their wives and daughters remained at the home farm to tend calves, milk cows, and make cheese. In the 1290s three such vaccaries were operated by women, probably

widows previously running them with husbands (Atkin 1994, p. 17). Another instance of family-based pastoral employment of married women comes from a fifteenth-century Sussex manor which employed married male shepherds and dairymen helped by wives and daughters (Mate 1999, p. 32). In 1509 a demesne in Suffolk employed a married woman to manage the dairy and do other pastoral work (Whittle 2005, p. 70).

A medieval woman thus did not have to stay unmarried to do pastoral work for a landlord. Many land-poor households could only survive if both husband and wife worked for landlords as wage-labourers. Such labourers did pastoral as well as arable work. Married women also worked for landlords in vaccary-keeping familial teams and as managers of demesne dairies. Women did not have to remain unmarried to benefit from rising pastoral wages paid by landlords after the Black Death, contrary to a key assumption of the VV model.

3.5 An unacceptable simplification

Any theoretical model has to make simplifying assumptions. But these are only acceptable if they abstract from non-essential complications without being crucial for the results of the model. The VV model is not an acceptable simplification, because it assumes away important aspects of the choices facing medieval English peasant women. Married females could work in pastoral agriculture both as wage-labourers for landlords and as peasant housewives on the family holding. If VV's model was altered by dropping the assumption that women had to choose between marriage on the one hand and pastoral employment as a servant on the other, higher wages for women in pastoral agriculture would no longer entail lower fertility. The result in VV's model that forms the basis of their argument that the Black Death led to the EMP depends critically on this untenable assumption.

Our emphasis on the fact that married women could work in pastoral agriculture does not mean that we regard servants as a minor source of hired labour, though, as we have noted, there is evidence suggesting that servants became a less important part of the labour force in the aftermath of the Black Death. Our point is that the existence of these pastoral employment opportunities for married women cannot be assumed away when analysing how the Black Death affected fertility. The higher wages in pastoral agriculture were available to both unmarried women working as servants and married women working as day-labourers, though the Humphries-Weisdorf evidence suggests that wages for the former increased much less, if

at all, than the latter. The effect of these higher wages on fertility will depend on several things. One is the relative sizes of the substitution and income effects that higher wages have on marriage and children. Another is women's attitudes to risk, since servanthood offers more secure employment than does working as a day-labourer. These considerations are missing from VV's analysis of the effects of higher pastoral wages on women's marriage and labour supply decisions. A satisfactory analysis will require recognition of heterogeneity in women's preferences with respect to marriage and risk. Lacking such analysis, it is not possible to state on theoretical grounds that rising pastoral earnings after the Black Death delayed marriage and reduced fertility.

4. Is there evidence of a causal relationship between pastoral agriculture and lower fertility?

Can it be argued that it does not matter that the VV theoretical model is driven by inaccurate assumptions, since the empirical findings support its predictions? The answer is no. The evidence advanced by VV does not in fact support the predictions of their model.

4.1 Pastoralism and the proportion of never-married females in 1381

The central argument of VV is that the expansion of pastoral agriculture after the Black Death caused lower nuptiality, because women could only do pastoral work outside marriage. VV believe that this view is supported by evidence of a causal relationship between the proportion of pastoral land in a county and the proportion of unmarried women there in the late fourteenth century (see VV (2013) Table 3). There are no data for the proportion of unmarried women in English counties at this time, but VV argue that an acceptable proxy is the proportional decrease in the number of taxpayers in a county between the 1377 and 1381 poll tax returns.

There are several reasons this argument fails to convince, which we discuss in Section A6 of the Appendix. We show there that the fall in taxpayer numbers from 1377 to 1381 resulted from under-recording of an unknown combination of poor not-currently-married men, poor not-currently-married women, and poor married persons of both sexes, a combination that almost certainly varied across counties. Hence the regression results in Table 3 of VV (2013) do not tell us anything about the relationship between pastoral land and

the proportion of never-married fertile women, which is what is needed in order to test VV's theory. VV's theory cannot be supported by the fourteenth-century data they mobilize.

4.2 Pastoralism and female age at first marriage

VV claim that their central argument is also supported by evidence that locations which were more pastoral before and after the Black Death had later female marriage age in the 1600-1837 period. VV's Table 4 appears to show that female age at first marriage (henceforth FAFM) in 1600-1837 was higher in locations that were (i) more pastoral before the Black Death and (ii) shifted more towards pastoral production after it. Their Table 5 appears to show that FAFM in 1600-1837 was higher in locations which had a contemporaneous pastoral marriage seasonality.

There are problems, as we shall see, with the empirical analysis reported in VV's Tables 4 and 5. But even if there were no such problems, these regressions do not support VV's argument that the Black Death caused the EMP. At most, these tables show that FAFM several hundred years after the Black Death was related to measures of past and contemporaneous pastoralism. If female marriage age is assumed to be persistent across several centuries, VV's claim that the shift to pastoral production made women delay marriage immediately after the Black Death is one possible explanation for why FAFM in the 1600-1837 period was higher in locations which had more pastoral agriculture before or after the Black Death. But there are other possible explanations rooted in the 1600-1837 period itself. One is the increasing regional specialization of agriculture, the growth of urban markets, and the adoption of new crops and techniques from the seventeenth century onwards. Regions agronomically suited to growing particular crops specialized more heavily in arable cultivation, while those more suited to running sheep for wool, fattening cattle, or raising dairy animals shifted more strongly to pastoral production (Overton 1996, pp. 103-5, 131; Coward and Gaunt 2017, p. 516). Regional specialization made those locations that were relatively pastoral in 1290 even more so in the eighteenth century, as formerly mixed farms converted to sheep-raising, cattle-raising, or specialized dairying. This eighteenth-century intensification of the pastoral specialization of already predominantly pastoral regions was likely to have increased the demand for female labour, creating incentives for women to delay marriage. The general point is that any link between marriage behaviour in the 1600-1837 period and the regional distribution of pastoral agriculture can be accounted for by other explanatory mechanisms than the Black Death.

Quite apart from their dubious relevance to the Black Death, there are a number of problems with the results that VV present about the relationship between pastoralism and FAFM 1600-1837. When these problems are addressed, there is no evidence of a positive causal relationship between these variables.

The dependent variable in VV's Tables 4 and 5 is the mean FAFM in the parishes located in a particular county, observed at five different periods (1625, 1675, 1725, 1775 and 1819).[7] VV Table 4 has two regressors relevant to their argument. One is the share of pastoral land in a county in 1290 (henceforth *Pastoral 1290*), which is interpreted as measuring the extent of pastoral agriculture before the Black Death. The other is the county-level number of deserted medieval villages per 100,000 acres (henceforth *DMV*), which is interpreted as measuring the shift from arable to pastoral production after the Black Death (VV Appendix, p. 25). Both variables raise measurement issues, for reasons discussed in detail in Appendix Section A5. In particular, *DMV* does not register desertion of villages in the aftermath of the Black Death, but rather over the entire period from the late eleventh to the eighteenth century. Hence it cannot be interpreted as a measure of the shift from arable to pastoral production following the Black Death, and the case for including it as a regressor is weak. Our preferred specification therefore omits *DMV* as a regressor. For a clear comparison with VV, we also report in Section A6 of the Appendix results from regressions that retain *DMV*.

The relevant regressor in VV's Table 5 is the county-level share of parishes with spring marriage seasonality c.1560 – c.1820. Kussmaul (1990) argues that marriage frequency which was high in spring but low in autumn indicates pastoralism, since pastoral workers typically married after lambing and arable workers after harvest. VV thus measure pastoralism by calculating the county-level share of parishes with spring marriage seasonality (henceforth *Pastoral Marriage*) using Kussmaul's 542 English parishes from 1561 to 1820.

To identify the causal effect of pastoralism on FAFM, instrumental variable (henceforth IV) estimation is necessary because a regression of FAFM on pastoralism variables and time-period variables almost certainly omits variables that influenced FAFM. VV Tables 4-5 report just-identified IV estimates using ln*(daysgrass)* as an IV for *Pastoral 1290* and *Pastoral Marriage*. The variable *daysgrass* is the number of days on which grass can grow in each county, based on twentieth-century climate data (Down et al. 1981). In their Appendix, VV use crop suitability – measured as the share of each county's area reaching a

[7] See Appendix Section A8 for a fuller discussion of this and other variables used in the regression analysis.

threshold yield for at least one of wheat, barley or rye – as a second IV to obtain over-identified estimates.[8]

Pastoral 1290, *Pastoral Marriage*, and *DMV* are all measured at the county level, while FAFM is measured at the parish level. VV therefore allow for the regression errors to be clustered at the county level. There are only 15 counties in their FAFM dataset, while the standard cluster-robust variance estimate assumes that the number of clusters tends to infinity. Cameron, Gelbach, and Miller (2008) recommend using a version of the wild cluster bootstrap to estimate the cluster-robust variance matrix when the number of clusters is small. We therefore report confidence intervals obtained from such a procedure, using the Stata *boottest* command of Roodman et al. (2019). For comparability with VV, we also report 95% confidence intervals based on the clustered standard errors from Stata's finite-sample adjustment, though in contrast to VV we use a small-sample adjustment for these.

The first four columns in Table 1 report estimates of the effect of *Pastoral 1290* on FAFM using the 112 observations in VV's FAFM dataset. All regressions in the table include four time-period dummy variables as regressors, the coefficients of which are not reported. For each pair of reported confidence intervals and *p* values in Table 1, the upper one is obtained using Stata's finite-sample adjustment, while the lower one is obtained using the wild cluster bootstrap with Rademacher weights and 9,999 replications (henceforth WCB). Equation (1.1) in Table 1 uses ln*(daysgrass)* as the single IV for *Pastoral 1290*, as VV do in their Table 4. The effective *F* statistic provides no evidence of weak IV problems.[9] There is clear evidence of a positive effect of *Pastoral 1290* on FAFM, though the elasticity corresponding to the point estimate is a modest 0.137.[10] A regression-based version of the Hausman test rejects the null hypothesis that *Pastoral 1290* can be treated as an exogenous variable, so just-identified IV estimation using ln*(daysgrass)* is preferable to OLS.

If crop suitability is also a strong IV for *Pastoral 1290*, it should be used as an IV together with ln*(daysgrass)* for inference; otherwise sample information would be wasted. Equation (1.2) in Table 1 shows the just-identified IV estimates using crop suitability. The effective *F* statistic shows that crop suitability is a strong IV. However, there is no clear evidence of a positive effect of *Pastoral 1290* on FAFM, the elasticity corresponding to the point estimate is very small, and the exogeneity test provides no evidence that IV estimation

[8] VV (2013), Appendix, p. 18.
[9] With a single IV, the Montiel Olea-Pflueger (2013) critical values for the null hypothesis that the TSLS estimator has a bias no larger than 5 and 10% of the worst case are 37.418 and 23.109 respectively.
[10] Here and subsequently all reported elasticities are calculated at sample mean values.

Table 1: IV and OLS estimates of the effect of the share of pastoral land in 1290 and pastoral marriage seasonality on female age at first marriage

	Estimation method				Estimation method			
	IV using ln*(daysgrass)*	IV using crop suitability	IV using ln*(daysgrass)* and crop suitability	OLS	IV using ln*(daysgrass)*	IV using crop suitability	IV using ln*(daysgrass)* and crop suitability	OLS
	(1.1)	(1.2)	(1.3)	(1.4)	(1.5)	(1.6)	(1.7)	(1.8)
Pastoral 1290	5.962	1.766	3.179	2.730	-	-	-	-
95%	[3.83, 8.10]	[-3.38, 6.91]	[-0.89, 7.25]	[-1.13, 6.60]	-	-	-	-
confidence interval	[1.12, 9.15]	[-6.07, 6.09]	[-∞, -13.9] U [-8.42, 6.28]	[-1.92, 6.07]				
Elasticity	0.137	0.040	0.073	0.063	-	-	-	-
Pastoral Marriage	-	-	-	-	9.488	3.667	7.321	3.288
95%	-	-	-	-	[7.24, 11.74]	[-4.82, 12.15]	[3.31, 11.33]	[-1.90, 8.48]
confidence interval					[6.71, 12.33]	[-∞, 10.43]	[-∞, -14.6] U [-3.06,15.69]	[-1.89, 9.03]
Elasticity	-	-	-	-	0.040	0.016	0.031	0.014
Effective *F* statistic	124.58	44.23	18.68	-	90.71	13.38	18.27	-
p value of exogeneity	0.000	0.295	0.625	-	0.000	0.906	0.013	-
test	0.033	0.338	0.722		0.029	0.916	0.142	
p value of test of just-identified estimates	-	-	0.127 0.089	-	-	-	0.167 0.077	-
p value of *J* test	-	-	0.030	-	-	-	0.023	-
Adjusted R^2	0.264	0.347	0.354	0.355	0.192	0.381	0.301	0.382

Notes: The number of observations for all equations is 112. All equations include four time-period dummy variables as regressors, the coefficients of which are not reported. These estimates were obtained using the Stata command *ivreg2* (Baum, Schaffer, and Stillman 2010). In each pair of confidence intervals and *p*-values, the upper one is based on Stata's finite-sample adjustment and the lower one is based on the wild cluster bootstrap. The elasticities correspond to the point estimate at sample mean values. The effective *F* statistic is that of Montiel Olea and Pflueger (2013). The *Pastoral Marriage* regressions are weighted by the number of parishes in each county for which the marriage pattern was reported by Kussmaul (1990).

Source: Authors' estimates.

is necessary.

Using both IVs also makes it possible to test the over-identification restriction and hence whether ln*(daysgrass)* and crop suitability are valid IVs for *Pastoral 1290*. Equation (1.3) shows the results. The effective *F* statistic suggests that this regression does not suffer from serious weak-IV problems.[11] The standard test of over-identification is Hansen's *J* statistic, but this may not be appropriate when the number of clusters is small. We therefore report as over-identification tests for equation (1.3) both the *p* value of the *J* statistic and *p* values of tests of the difference between the estimates of *Pastoral 1290* in equations (1.1) and (1.2). The two latter tests are based on clustered standard errors from Stata's finite-sample adjustment and from the WCB procedure. The *J* test rejects the over-identification restriction in (1.3) at conventional levels. The *p* value of the WCB test of the difference between the two just-identified IV estimates of the effect of *Pastoral 1290* in equations (1.1) and (1.2) is 0.089, though it is 0.127 if the less satisfactory Stata finite-sample adjustment is used. In any case, because the most serious consequences of an incorrect decision in an over-identification test arise from type II error, failure to reject the restriction at *p* values of 0.10-0.15 does not mean that the test has been passed, since its power will be low. These over-identification tests show that at least one of ln*(daysgrass)* and crop suitability does not satisfy the exclusion restriction required to be a valid IV.

The number of days on which grass can grow indicates climatic conditions which are positively associated with pastoral agriculture, while crop suitability indicates land conditions which are negatively associated with pastoral agriculture. These variables certainly reflect natural influences on the extent of pastoral agriculture in different English counties. But it is extremely unlikely that a location's climatic and land suitability for pastoral agriculture should affect FAFM in 1600-1837 solely via the share of pastoral land in 1290, which is the condition required for these variables to be valid IVs. As discussed above, the eighteenth-century intensification of regional specialization in pastoral production was likely to have influenced FAFM. From the seventeenth century onwards, there was also a gradual shift from sickles to scythes in harvesting grain (Roberts 1979, pp. 16-8; Snell 1985; Overton 1996, p. 188). This decreased female relative to male productivity in arable agriculture and gradually reduced women's relative wages between the late sixteenth century and c. 1725 (Roberts

[11] With two IVs, the Montiel Olea-Pflueger (2013) critical values for the null hypothesis that the TSLS estimator has a bias no larger than 5 and 10% of the worst case are 23.097 and 14.713 respectively.

1979, pp. 18-9). Other things equal, this would have reduced female labour force participation in arable regions, motivating women to marry earlier. Since the technological shift did not affect women's labour productivity in pastoral regions, it would have left female labour force participation there unchanged and FAFM in those regions unaffected. As a result, a positive relationship between pastoral regions and FAFM was likely to emerge in the early modern period, since arable regions saw falling female labour productivity and stronger marriage incentives for women, while pastoral regions did not.

These developments make it probable that climatic and land conditions in a particular location directly affected FAFM there in 1600-1837, in addition to any effect that may have operated via the share of pastoral land in 1290. If so, both ln*(daysgrass)* and crop suitability are invalid IVs. The over-identification tests suggest that at least one IV is invalid, and even if one of the two variables is a valid IV, there is no way of knowing which it is. Thus we do not believe that it is possible for any of equations (1.1) – (1.3) to yield causal estimates of the effect of *Pastoral 1290* on FAFM. At best, VV's data make it possible to estimate an association between *Pastoral 1290* and FAFM. Equation (1.4) shows that this association is very small and poorly determined. Furthermore, the exogeneity tests in (1.2) and (1.3) provide no evidence that the IV estimates in these equations are preferable to the OLS ones in (1.4).

Equations (1.5) – (1.8) in Table 1 shows estimates of the effect of roughly contemporaneous spring marriage seasonality on FAFM in 1600-1837. A detailed discussion of these results is not necessary, because they resemble those in equations (1.1) – (1.4). When ln*(daysgrass)* is used as the single IV for *Pastoral Marriage*, in equation (1.5), there is no evidence of weak-IV problems, and the effect of *Pastoral Marriage* on FAFM is precisely estimated. When crop suitability is used, in (1.6), there is evidence of weak-IV problems, and the estimated effect of *Pastoral Marriage* is poorly determined.[12] The case for focusing on the over-identified IV estimates in (1.7) is less compelling, since crop suitability is not a strong IV. Nevertheless, the tests of the over-identification restriction in (1.7) suggest that at least one of the two IVs is not a valid IV for *Pastoral Marriage*. The *J* test rejects the over-identification restriction at conventional levels, and the *p* value of the WCB test of the difference between the two IV estimates in equations (1.5) and (1.6) is 0.077. Thus it is not possible to obtain causal estimates of the effect of *Pastoral Marriage* on FAFM. The most

[12] With a single IV, the Montiel Olea-Pflueger (2013) critical values for the null hypothesis that the TSLS estimator has a bias no larger than 20 and 30% of the worst case are 15.062 and 12.039 respectively.

that VV's data permit is an estimate of the association between them, which equation (1.8) shows to be extremely small and poorly determined. Even if one were to focus on the largest and most precise IV estimate, in (2.1), its economic significance is tiny, with the elasticity corresponding to the point estimate being 0.04.

VV's estimates of the causal effect of *Pastoral 1290* and *Pastoral Marriage* on FAFM several hundred years after the Black Death are based on the use of IVs which fail to satisfy the exclusion restriction. Furthermore, the VV estimates do not use the recommended wild cluster bootstrap procedure for obtaining standard errors when the number of clusters is small. The estimates reported in Table 1 show that there is no evidence of an economically or statistically significant relationship between these pastoralism measures and FAFM. Quite aside from the dubious pertinence of a relationship between pastoralism and FAFM post-1600 to the immediate demographic effects of the Black Death in 1350, there is no evidence that any such relationship existed.

5. Conclusion

Did the Black Death create the EMP, thereby freeing western Europe from Malthusian limits on growth? Careful examination reveals pervasive problems with this argument, affecting the basic premise, the underlying theoretical model, and the empirical analysis.

There is no evidence that the EMP originated in rural England in the aftermath of the Black Death. The evidence on medieval English demography is so sparse and fragile that scholars disagree fundamentally about marriage age before the 1540s, the earliest date for which parish register data are available and family reconstitution is therefore possible. The one point on which there appears to be a consensus among historical demographers who study medieval England is that, whenever the EMP did emerge in the English countryside, it was not directly after the Black Death. VV's basic premise is wrong.

Women's wages in pastoral agriculture increased after the Black Death, but the effect of higher wages on marriage and fertility is ambiguous in general because wages have income and substitution effects that work in opposite directions. VV's theoretical model predicts that these higher wages led to later marriage and lower fertility on the basis of one untestable assumption about preferences, and two testable ones about women's labour market opportunities: first, that women could only work in the pastoral sector if they worked for landlords; and second, that in order to work for landlords, women had to remain unmarried. If

either one of these two testable assumptions does not hold, VV's model does not predict that EMP behaviour will emerge after an increase in the aggregate land-labour ratio. The historical evidence makes it quite clear that these two testable assumptions did not hold in medieval England.

The quantitative evidence presented by VV is also flawed. VV claim that there is a cross-sectional relationship between pastoralism and the proportion of never-married fertile women in late-fourteenth-century England, but the proxy they use for the latter in their empirical analysis is best interpreted as measuring the proportion of poor people in a location, not the proportion of never-married fertile women there. VV's evidence of a positive relationship between pastoralism and female marriage age in the period c. 1600 – c. 1837 disappears once the appropriate procedure for obtaining a cluster-robust variance matrix with a small number of clusters is employed and careful attention is paid to the validity of the IVs. But even if this problem did not exist, a relationship between pastoralism and female marriage age several hundred years after the Black Death is not relevant to VV's argument about the demographic effects of the Black Death.

What are the wider implications of being forced to abandon the argument that the Black Death led to the emergence of the EMP in England? If it were the case that the exogenous shock of the Black Death led to the emergence of the EMP, then the EMP could be taken as an exogenous cause of higher living standards in those societies that had it. However, as we have shown, the claim that fertility restriction in England was caused by the Black Death does not stand up to scrutiny. This means that analyses of the causal effects of fertility restriction on pre-industrial growth have to take account of the effects of living standards on marriage and fertility as well the reverse effects. Further research will be required to understand when and how pre-industrial people managed to calibrate their fertility to the productive capacities of the economy, thereby freeing themselves of Malthusian shackles on growth. The EMP is not an exogenous cause of economic development.

Supplementary material

Supplementary material is available on the OUP website. This material comprises the online Appendix, the data file, and the replication files.

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Did the Black Death cause economic development by 'inventing' fertility restriction?

Jeremy Edwards and Sheilagh Ogilvie

Appendix

This appendix provides additional detail on a number of points made in the main text. Section A1 outlines the VV model of women's fertility and pastoral labour supply behaviour in order to highlight the key assumptions discussed in Section 2 of the main text. Sections A2-A5 provide further historical detail to substantiate the arguments advanced in Section 3 of the main text pointing out that the key premises of the VV model are inconsistent with the evidence. Section A6 considers whether the proportional drop in taxpayers between the 1377 and 1381 tax returns can be interpreted as a measure of the proportion of unmarried women of fertile age. Section A7 presents evidence concerning age- and gender-specific marital status in English populations in the early modern period, when it is known that the EMP prevailed, to substantiate the interpretation of the 1377 and 1381 poll tax results presented in Section 4.1 of the main text. To support the discussion in Section 4.2 of the main text, Section A8 discusses the variables used in the regression analysis in greater detail, and Section A9 reports the results of estimating regression models of female age at first marriage which include the number of deserted villages per 100,000 acres as well as the share of pastoral land in 1290.

A1. Female fertility and pastoral labour supply in the VV model

Section 2 of the main text discusses the two key assumptions which underlie VV's theoretical analysis. One is that women can only work in pastoral agriculture if they are unmarried. This can be tested, and as we show in the main text, the evidence from medieval England clearly falsifies it. The other is that women's preferences involve a basic-needs level of consumption below which increases in income lead entirely to greater consumption rather than additional children. This is not testable, so in order to clarify the role of this special assumption about preferences, we present a formal analysis here. Our presentation draws heavily on VV's analysis, and is provided for purposes of clarification.

VV define the EMP as a demographic regime in which fertility is below the maximum possible and varies positively with per capita income (VV 2013, p. 2235). They then

construct a model which shows that such a regime can emerge following an exogenous increase in the aggregate land-labour ratio. In their model, women's only choice is whether to work in arable or in pastoral agriculture. Women differ in their labour productivity in arable but are all equally productive in pastoral work. Women can only work in the pastoral sector if they are employed by landlords as servants, which requires them to stay unmarried. All women have to marry at some point, so there is a maximum amount of time that a woman can work in pastoral agriculture, which is less than the total labour she supplies. A married woman can only work on her husband's peasant holding, which can only engage in arable production. A woman's fertility depends solely on the amount of time she spends working in the pastoral sector. A woman who works for as long as possible in pastoral production has the minimum number of children, and a woman who never works in the pastoral sector has the maximum number. All women are assumed to have the same preferences for children, which they can only have by getting married, so whether a woman remains unmarried and works in pastoral agriculture depends on the wage she can earn in the pastoral sector relative to her marginal product in the arable sector. This relative wage depends on the land-labour ratio in the pastoral sector, which moves in the same direction as the economy's aggregate land-labour ratio provided that both arable and pastoral production take place. Whether a woman with a particular marginal product in the arable sector can earn more in the pastoral sector thus depends on the aggregate land-labour ratio. Provided that this land-labour ratio is such that at least some women can earn more in the pastoral than the arable sector, and provided that one other condition (discussed below) is met, these women will choose to remain unmarried for some time. How long they do so depends on their preferences.

VV assume that all women have identical preferences for children and a composite consumption good, which take a very special form. Women have a basic-needs level of consumption below which the marginal utility of consumption is very high and above which it falls rapidly. This preference specification means that the pastoral labour supplied by a given woman, and thus her fertility, depends not only on the pastoral wage relative to her marginal productivity in arable agriculture but also on whether her income is above or below the basic-needs consumption level at the relative wage which makes pastoral work worthwhile. The VV model therefore generates a complex pattern of pastoral labour supply behaviour, which enables it to explain why the Black Death did not invariably lead to the EMP.

More formally, an adult woman supplies one unit of labour inelastically, either in pastoral (l_h) or in arable work ($1 - l_h$). The maximum amount of pastoral labour she can

supply is $\bar{l}$. She has to remain unmarried, and thus does not have children, if she works in the pastoral sector. When she marries, she works in the arable sector and has $b = \pi(1 - l_h)$ children, where π is the number of births per unit time. The wage she can earn in pastoral work is $w_h(t)$, which depends on the aggregate land-labour ratio, t. Her marginal product in arable agriculture, which also depends on the aggregate land-labour ratio, is $w_{Fg}(t)$. Her consumption is therefore $C = w_h(t)l_h + w_{Fg}(t)\ (1 - l_h)$. Both $w_h(t)/w_{Fg}(t)$ and $w_{Fg}(t)$ increase with t (see VV Appendix equation A.4).

All women have the same preferences in the VV model. The form of these preferences differs according to whether consumption is above or below a basic-needs level $\underline{c}$, so that a woman's utility function is

$$u(C, b) = (1 - \mu)\ln\left(C - \underline{c} + \epsilon\right) + \mu \ln\left(b - \underline{b}\right) \quad \text{if } C > \underline{c}$$

$$u(C, b) = (1 - \mu)\left[\left(C - \underline{c}\right)/\epsilon\right] + \mu \ln\left(b - \underline{b}\right) \quad \text{if } C \leq \underline{c}$$

Here $0 < \mu < 1$ is a preference parameter, ϵ is a positive number close to zero, and $\underline{b} = \pi(1 - \bar{l})$ is the minimum number of children that a woman must have. This specification of preferences means that the marginal utility of consumption is very large relative to the marginal utility of children for consumption below the basic-needs level. The basic-needs level of consumption plays a major role in the VV analysis, for two reasons. One is that this specification of preferences means that women value consumption very highly relative to children for consumption below the basic-needs level, but much less highly for consumption above it. The other is that the relationship of the basic-needs level of consumption to a woman's consumption when she works for as long as possible in the pastoral sector influences her fertility decision, as will become clear.

A woman therefore chooses l_h (and hence b) to maximise her utility subject to the constraint that $0 \leq l_h \leq \bar{l}$. If the aggregate land-labour ratio $t < t_A$, where t_A is such that $w_h(t_A) = w_{Fg}(t_A)$, she will supply no pastoral labour and her fertility will be at the maximum. Thus a necessary condition for her to work in the pastoral sector is $t > t_A$. In what follows, we focus on the case in which this necessary condition is satisfied.

Let $I(t) \equiv w_h(t)\bar{l} + w_{Fg}(t)(1 - \bar{l})$ be the consumption that a woman has at the aggregate land-labour ratio t if she works for as long as possible in the pastoral sector. Define t_B as the aggregate land-labour ratio at which such a woman can afford the basic-needs consumption if she works for the maximum amount of time in the pastoral sector: $I(t_B) \equiv \underline{c}$.

We first consider the case in which a woman cannot afford the basic-needs consumption level when $t = t_A$. Suppose initially that the pastoral wage a woman can earn is not high enough for her to consume the basic-needs level even if she works as long as possible in the pastoral sector, i.e., $t_A < t < t_B$. Then the solution to her utility-maximisation problem is

$$l_h = \bar{l} - \frac{\mu}{1-\mu}\frac{\epsilon}{w_h(t) - w_{Fg}(t)} \tag{1}$$

and, since ϵ is a very small positive number, she will work for almost the maximum possible amount of time in the pastoral sector, and her fertility will be almost at the minimum.

Now suppose that the aggregate land-labour ratio is such that, if she works as long as possible in the pastoral sector, she can consume more than the basic-needs level, i.e., $t_A < t_B < t$. In this case the solution to her utility-maximisation problem is

$$l_h = (1-\mu)\bar{l} - \mu\frac{w_{Fg}(t) - \underline{c} + \epsilon}{w_h(t) - w_{Fg}(t)}. \tag{2}$$

In order for l_h to be positive, the following condition must hold:

$$w_h(t) - w_{Fg}(t) > \frac{\mu}{(1-\mu)\bar{l}}\left(w_{Fg}(t) - \underline{c} + \epsilon\right). \tag{3}$$

The definition of t_B implies that

$$w_{Fg}(t_B) = \underline{c} - \left(w_h(t_B) - w_{Fg}(t_B)\right)\bar{l}. \tag{4}$$

Since $t_A < t_B$, $w_h(t_B) - w_{Fg}(t_B) > 0$, and thus $w_{Fg}(t_B) < \underline{c}$, so the condition for l_h to be positive will be satisfied at t_B. Using (4) in (2) shows that at t_B the woman's pastoral labour supply is just below $\bar{l}$. Defining

$$Z(t) = \frac{1 - \left(\underline{c}/w_{Fg}(t)\right)}{\left(w_h(t)/w_{Fg}(t)\right) - 1}$$

(2) can be written as

$$l_h = (1-\mu)\bar{l} - \mu Z(t) - \frac{\mu\epsilon}{w_h(t) - w_{Fg}(t)}. \tag{5}$$

VV show in their Appendix A.1 that, for $t_A < t_B < t$, $\partial Z(t)/\partial t > 0$ for a range of $t > t_B$ before $\partial Z(t)/\partial t$ becomes negative for sufficiently large t, and $\lim_{t\to\infty} Z(t) = 0$. Hence, as the aggregate land-labour ratio increases, pastoral labour supply falls from just below $\bar{l}$ at t_B and tends to $(1-\mu)\bar{l}$ as t becomes very large.

Equations (1), (2) and (5) together show that, when an increase in the land-labour ratio makes pastoral work worthwhile for a woman before it allows her to afford the basic-

needs level of consumption, her pastoral labour supply is as follows. Initially it is zero, but as the aggregate land-labour ratio increases, her pastoral labour supply will jump to nearly the maximum possible when the pastoral wage exceeds her arable marginal productivity, and remain at that level until it becomes possible for her to afford consumption above the basic-needs level. At that point, her pastoral labour supply will begin to fall as pastoral wages increase, and as pastoral wages become very high it will converge to $(1-\mu)\bar{l}$. This means that her fertility will initally be at the maximum, then fall to almost the minimum, and then rise over a range of pastoral wages, thus generating EMP behaviour for a range of values of the aggregate land-labour ratio.

Now consider the case in which a woman can afford the basic-needs level of consumption at a pastoral wage for which pastoral work is not worthwhile. In this case, $t_B < t_A$, and, since $I(t_A) > \underline{c}$, $w_{Fg}(t_A) > \underline{c}$. Condition (3) is still necessary for pastoral labour supply to be positive. Thus for a range of values of $t_A \leq t \leq t_C$ such that

$$w_h(t) - w_{Fg}(t) \leq \frac{\mu}{(1-\mu)\bar{l}}\left(w_{Fg}(t) - \underline{c} + \epsilon\right) \tag{6}$$

$l_h = 0$ is a utility-maximising choice. Condition (6) is the first-order necessary condition for $l_h = 0$ to solve the utility-maximisation problem. Since $w_{Fg}(t_A) > \underline{c}$ in this case, a pastoral wage above a woman's arable marginal product is not sufficient for her to supply pastoral labour: in order for her to do so, the pastoral wage premium has to be greater than the right-hand-side of (6), which is positive. This is because the opportunity cost of a woman working in the pastoral sector is not just her foregone arable marginal product: she also gives up some children. Hence the pastoral wage must exceed her arable marginal product by an amount that is sufficient to compensate her for the foregone children before she will supply any pastoral labour.

Using (5), the condition for a woman to supply pastoral labour is

$$Z(t) < \frac{(1-\mu)\bar{l}}{\mu} - \frac{\epsilon}{w_h(t) - w_{Fg}(t)}.$$

For the case in which $t_B < t_A$, VV show in their Appendix A.1 that $\lim_{t \downarrow t_A} Z(t) = \infty$ and $\lim_{t \to \infty} Z(t) = 0$. Thus a woman who is able to afford the basic-needs level of consumption when the pastoral wage is below her arable marginal product will not work in the pastoral sector as soon as the pastoral wage premium becomes positive. However, a sufficiently high aggregate land-labour ratio, and hence a sufficiently high pastoral wage premium, will lead

her to supply pastoral labour. For very high values of the pastoral wage her pastoral labour supply will converge to $(1-\mu)\bar{l}$.

The fertility of a woman in this case will therefore remain at the maximum for a range of values of the pastoral wage above her arable marginal product. For a sufficiently high pastoral wage her fertility will decline from the maximum, and eventually converge to a value above the minimum. But her fertility will never decline to the minimum and subsequently rise, and thus will not exhibit EMP behaviour.

It is clear that, even with the assumption that women have to be unmarried in order to work in the pastoral sector, the VV model is critically dependent on the existence of a basic-needs level of consumption in order to generate EMP behaviour in response to an increase in the aggregate land-labour ratio. If women's preferences did not have this special feature, (i.e., if $\underline{c} = 0$), then a woman's pastoral labour supply and fertility behaviour in the VV model would always have the non-EMP features described in the preceding two paragraphs. The importance of this assumption about preferences means that it should receive some justification, but VV provide no evidence in support of it.

In the VV model, therefore, the Black Death, by causing a large exogenous increase in the aggregate land-labour ratio which raises the pastoral sector wage for women relative to their arable marginal product, can lead to the emergence of the EMP, provided that there are some women whose income is below the basic-needs level for the values of the wage that make pastoral work just worthwhile. Proposition 2 of VV states this result formally. It follows that an increase in the land-labour ratio will only lead to the EMP in an economy with features that lead to this outcome. These features include relatively low female and total factor productivity in arable agriculture, and relatively high total factor productivity in pastoral agriculture (VV 2013, p. 2245, Corollary 2).

A2. Did the EMP emerge at the time of the Black Death?

There is an extensive literature in medieval history and historical demography on the question of the historical period at which the EMP originated. VV state that 'there is a consensus that the EMP only became fully developed after the Black Death in 1348-1350' (VV, p. 2228). But this is not the case. No such consensus exists. The demographic evidence for medieval England is sparse and ambiguous. Historical demographers disagree fundamentally about when the EMP developed. Some believe that it already prevailed in

England long before 1350. Others argue that that England was characterized by early and universal marriage throughout the medieval period, and that the EMP only emerged in the sixteenth century. A minority of scholars posit a discontinuity in marriage behaviour around 1350, but hold diametrically opposed views, with some arguing that the Black Death in fact made women marry earlier and more universally to replace population losses while others contend that it created incentives for them to marry later and less universally – though mainly in towns.

VV adduce two references to support their statement that there is a scholarly consensus that the EMP developed in the aftermath of the Black Death (pp. 2228, 2232). The first is Hajnal (1965). But this is puzzling. Hajnal in fact concluded that for England, 'the little fragmentary evidence which exists for the Middle Ages suggests a non-European pattern' (Hajnal 1965, p. 134). He regarded English marriage patterns in 1377, a generation after the Black Death, as being 'not at all like that of the eighteenth-century Europe, but much more like that of non-European civilizations' (Hajnal 1965, p. 119). He speculated that that the fundamental shift in marriage behaviour might have occurred 'between 1400 and 1650' (p. 122) and that the origins of the EMP 'lie somewhere about the sixteenth century' (p. 134). Thus when Hajnal originated the concept of the EMP in 1965, he did not think that it had arisen in the aftermath of the Black Death; his best guess was that it dated from centuries later.

VV's second reference, Herlihy (1997), cannot be said to represent a consensus view. In this unpublished 1985 lecture, which appeared posthumously, Herlihy interpreted a positive association between wealth and household size as implying that medieval Europeans adjusted fertility to match their resources. His main source on the positive association between wealth and household size was a document dating from the ninth century, demonstrating that this association long pre-dated the Black Death (Herlihy 1997, pp. 53-4). Herlihy tentatively speculated that the Black Death might have moved a larger share of the population into social strata which engaged in such prudential adjustment, but he did not present any evidence to support this conjecture (Herlihy 1997, pp. 56-7). Nor did he consider alternative explanations: small households among the poor need not indicate prudential fertility, but could instead reflect poor families shedding offspring or suffering higher mortality. Herlihy's tentative conjecture has never been widely adopted.

By contrast, a number of historical demographers hold that the EMP already existed in England before the Black Death (Smith 1979, pp. 96-101; Smith 1983, pp. 120-4, 128; Hallam 1985, pp. 55-6; Goldberg 1986b, pp. 142, 152-5; Smith 1990a, p. 173; Smith 1990b,

p. 55; Goldberg 1991, pp. 88-9; Bennett 2015, pp. 302, 307-10, 318). Quantitative data on medieval English marriage are sparse and scattered, but these scholars interpret them as indicating behaviour consistent with the EMP in the period before 1350. According to Smith (1990a, p. 173), 'In England, late age and low incidence of female marriage seem to be attributes widely characteristic of society ... from at least the thirteenth century'. Qualitative evidence is more plentiful, and this strand of scholarship points out that before 1350 England manifested all the social features typically associated with the EMP: female life-cycle service, limited segmentation of the labour market by sex, legal institutions enabling females to be economically active without being married, high geographical mobility for women, companionate marriage, bilaterally defined kinship, neo-local residence at marriage, high levels of remarriage, narrow age-gaps between spouses, and a significant number of brides being older than their bridegrooms at first marriage. This combination of quantitative and qualitative evidence is held to demonstrate that at the time of the Black Death 'the European marriage pattern was firmly in place with other necessarily attendant features of the social structure' (Smith 1990b, p. 55).

By 1982, such evidence had already led Hajnal to abandon his original conjecture that the EMP had emerged in the sixteenth century. Instead, Hajnal had become convinced that behavioural features associated with the EMP 'can be traced back for perhaps four centuries prior to 1600' and that 'aspects of the Northwest European household formation system can be shown to be very old indeed' (Hajnal 1982, p. 477).

So fragile is the evidence on medieval English demography that Hajnal is not the only scholar to have changed his interpretation of it. Goldberg, for instance, originally held that the EMP was an abiding feature of English demography pre-dating 1350 (Goldberg 1992c, pp. 204-15, 324-8). More recently, however, Goldberg has come to place greater weight on change in the aftermath of the Black Death (Goldberg 2013, p. 11). But neither his original nor his recent view supports the VV notion that the EMP emerged after the Black Death in the *rural* economy. Goldberg believes that it was women in *towns* who manifested behavioural patterns associated with the EMP – to some extent before the Black Death and increasingly afterwards (Goldberg 1986b, pp. 153-6, 160, Goldberg 1992c, pp. 108, 112-3, 122, 225-32; Goldberg 2013, pp. 9-10). In the countryside, he believes, female marriage remained early and universal long after 1350: 'Age data are confined to the century or more after the Black Death ... these suggest that by this later date women in rural society often married in their late teens or early twenties, whereas in towns women married later ... perhaps nearer their mid twenties' (Goldberg 1992c, p. 112). In towns, according to Goldberg, the

labour scarcity caused by the Black Death accelerated the emergence of the EMP by offering women more attractive jobs in crafts, commerce, and services, which encouraged them to delay leaving the labour force to get married; he thus ascribes the emergence of the EMP in England to a changing trade-off between two female labour-market choices which are not included at all in the VV model: non-agricultural work and leaving the labour force altogether (Goldberg 2013, pp. 13-4, 24-6).

The fragility and ambiguity of the data on medieval demography are strikingly illustrated by the existence of a diametrically opposed strand of medieval scholarship, which holds that the EMP only arose in England after 1500 (Hatcher 1977, pp. 56-7; Razi 1980; Hatcher 1986; Bailey 1996; Mate 1998, pp. 21-31; Mate 1999, pp. 59-60; Hatcher 2003, pp. 93-5; Hatcher, Piper and Stone 2006; Benedictow 2012). According to these scholars, medieval English mortality was so high that it would have required universal and early female marriage simply to maintain population size (Dyer 1980, pp. 229-30; Hatcher 1986; Harvey 1993, pp. 114-29; Bailey 1996, p. 2; Ecclestone 1999, pp. 21-7; Hatcher, Piper and Stone 2006; Benedictow 2012, pp. 10, 13-4, 22-3). The earliest surviving English parish registers of the 1540s and 1550s, according to this strand of scholarship, display virtually universal marriage and high birth-rates, which these scholars interpret as demonstrating the survival of a non-EMP marriage pattern from the medieval period into the mid-sixteenth century (Hatcher 1977, pp. 56, 65-6; Hatcher 2003, pp. 100-4). According to this school of thought, medieval English women married between the ages of 15 and 20 both before and after the Black Death; the EMP only emerged between the first and second quarter of the sixteenth century with the disappearance of the crisis mortality that had sustained the medieval demographic regime of early and universal marriage (Bailey 1996, p. 16; Hatcher 2003, pp. 94-6, 100-3, 113; Benedictow 2012, pp. 27-8).

These scholars are also sceptical of claims that female life-cycle servanthood, which is a central behavioural feature of the EMP, prevailed in England before the late fifteenth century (Bailey 1996, pp. 4-14). They argue that there is no clear evidence concerning 'the numbers of male or female servants, either before the Black Death or after it, so that it is impossible to say whether the proportion of single female servants actually increased, or whether they stayed at work longer than they had done earlier' (Mate 1999, p. 59). In so far as female servants existed, 'a significant number of young women left service before their mid-twenties in order to marry' (Mate 1999, p. 60). These scholars do not deny that *some* women in large towns delayed marriage until their mid-twenties, but argue that the data are too fragile to establish that 'the *majority* of women, over the country at large, married late',

and they are particularly doubtful that late marriage can have been common in rural areas (Mate 1999, p. 60).

Some adherents of this view go so far as to argue that England moved further away from the EMP after 1350. Hatcher and Bailey, for instance, hold that the Black Death increased wage levels and land availability, enabling couples to marry younger and more universally, pushing up fertility (Hatcher 1977, pp. 56-7; Bailey 1996, p. 3). Razi argues that peasants married early and universally before 1350 despite land scarcity and low wages; after the Black Death, plentiful land and high wages encouraged them to marry 'as early in life as the previous period, or even earlier' (Razi 1980, pp. 60-3, 74-91, 131-8). Across the whole period from 1270 to 1400, he argues, marriage behaviour among English peasants resembled that of fourteenth-century Italy, not the EMP of later sixteenth-century England (Razi 1980, p. 137). According to Bailey and Mate, early and universal marriage was compatible with plague-induced wage increases and rising female labour-force participation: 'Women ... married relatively early, but supplemented the familial income with casual labour after marriage' (Bailey 1996, pp. 13-4; Mate 1999, p. 59 (quotation)).

There is thus no scholarly consensus that the EMP emerged in the aftermath of the Black Death. The available evidence is so fragile and ambiguous that it supports a wide range of incommensurate views. Some argue that the EMP originated well before the Black Death, others that it did not arise before the 1540s. Some think the Black Death changed English nuptiality, but in the opposite way to the EMP, by improving incomes which encouraged early and universal marriage. Even those who speculate that the Black Death encouraged later marriage think it did so by improving women's opportunities in towns, while females in the rural economy continued to marry early and universally.

In sober fact, the data are inadequate to reach a definitive conclusion about when the EMP emerged. Reliable statistics on marriage age and lifetime celibacy require sources such as parish registers and village censuses, which are unavailable for England before the 1540s (Dennison and Ogilvie 2016, p. 211). The few data available are insufficient to sustain the proposition that the EMP emerged in England in the aftermath of the Black Death, and there is certainly no scholarly consensus that it did so.

A3. Peasants and pastoral production in medieval and early modern England

The first crucial assumption of the VV model is that the technology of pastoral production was available only to landlords and not to peasants. VV argue that size differences

between arable and pastoral farms in medieval England justify assuming that only landlords engaged in pastoral agriculture (VV 2013, p. 2238). An alternative assumption which would achieve the same effect, they note, is that there was a minimum land requirement for pastoral production (VV 2013, p. 2238, n. 27). However, the rich evidence on English agriculture, both before and after the Black Death, shows that the technology of pastoral production was available to peasants operating on small landholdings.

Medieval English peasants typically engaged in both arable and pastoral agriculture. They did this on land they held as tenants, as well as using their grazing rights on communal village pasture and on the stubble of the village's open arable fields in the post-harvest period. Keeping livestock was central to peasant agriculture in medieval England, even in primarily arable regions. One major reason for keeping animals was that their manure was the dominant source of fertilizer for the arable fields. A typical peasant household kept animals which it turned out onto the one-third of its arable land that was left fallow each year in the three-field rotation system, and then released to graze on the stubble from the cultivated fields. Arable and pastoral farming were complementary. A second major reason to keep animals was that peasants used their animals' milk, meat, hides, and (in the case of sheep) wool both for their own households and to sell on the market. The vast majority of peasant enterprises in medieval England were mixed farms, neither purely arable nor purely pastoral. Both landlords and peasants engaged in both arable and pastoral production, and both exploited all types of land: arable fields, meadows, pastures, and woodland (Dyer 2016, pp. 67-8). Indeed, landlords and tenants often shared assets, with both parties holding land in the open arable fields and both putting their animals out to graze on the same pasture (Dyer 2016, p. 65).

The amount of land worked by a peasant family was usually small. In the thirteenth century in East Anglia a prosperous minority had 10-25 acres but 80% of tenants had less than five acres. At the same period most Midland villages had a substantial proportion of tenants with 15-30 acres, but also a substantial minority of tenants with five acres or less: in the hundreds of Kineton and Stoneleigh in 1279, 40% of tenants held eight acres or less, 26% 15 acres, 28% 30 acres, and 6% over 30 acres (Dyer 1981, p. 5; Dyer 2005, p. 78).

Before the Black Death, peasant holdings of livestock were also typically small. In 1225, 198 villagers of the village of South Domerham had 3,760 sheep, an average of roughly 19 per villager (Power 1941, p. 20). In Warwickshire, there are no references to peasants having more than 10 cattle or 100 sheep in the period before 1349 (Dyer 1981, p. 30). In the Suffolk village of Coney Weston in 1302, 54 villeins (enserfed peasants) owned a total of 60

horses, 51 pigs, 117 cattle, and 342 sheep, with ownership being concentrated in the hands of just 16 villeins (Masschaele 1997, pp. 45-6). In the period 1287-1349, villagers on the Buckinghamshire manor of Iver supported themselves primarily through stock-raising and fishing (Bennett 1986, p. 26; Bennett 1987, p. 177). In the thirteenth and early fourteenth centuries, Cotswold villages shared upland pastures, accused each other of exceeding pasturing quotas, and seized animals from inhabitants of other villages (Dyer 2005, p. 63). Around 1300, in one Gloucestershire village each new holder of arable land had the entitlement to graze four beasts, a horse, and 30 sheep on the common pasture (Dyer 2005, p. 64-6).

Thus, in the period before the Black Death, average peasant land and livestock holdings were small, albeit with considerable variation across individuals. But even at this low level of production peasants produced arable and pastoral output for sale as well as their own consumption. Peasants almost invariably had to pay money rents to landlords, which required them to sell some output on the market. Furthermore, a peasant with sheep or cattle had to produce for a market, since the wool or hides could not all be consumed within the family (Power 1941, p. 3).

Quantitatively, peasant pastoral production was substantial. Even before the Black Death, some peasants owned sizeable herds, in some cases comparable to those of landlords. A 1225 Wiltshire tax assessment shows the number of sheep per taxpayer varying across villages depending on the type of husbandry, but averaging 15 over the whole area (Hilton 1966, p. 107). Around 1250, 170 named peasants illegally erected animal sheds in the royal forest at Feckenham, with the offending animals comprising 280 draught beasts, 100 horses, 25 mares, 154 oxen, 40 cows, 135 goats, 550 sheep, and 122 pigs (Hilton 1966, pp. 109-10). In the Suffolk Hundred of Blackbourne in 1283, the stocking density (number of livestock units per 100 acres of sown land) was 2.2 times higher on peasant holdings than on the landlord demesne (Slavin 2015, pp. 13-4). On one Gloucester Abbey manor in 1291, two peasants were each grazing 100 sheep on the landlord's meadow, and 33 other peasants were illicitly grazing a total of 68 animals (Dyer 2005, p. 63-4). A tenant at Minchinhampton in 1294 was fined for having 100 sheep in the landlord's oats (Hilton 1966, p. 109). Surviving tax assessment rolls for 1290-1334 show peasants owning considerable numbers of sheep in pastoral districts such as Holderness, the South Downs, and Wiltshire (Bennett 1987 [1937], p. 90). In 1312, peasants in the Worcestershire village of Kemerton impounded 400 sheep belonging to villagers on the other side of Bredon Hill (Dyer 2005, p. 63). In 1313, in the Wiltshire village of Minety the average number of sheep per taxpayer was 13.4 and the

median was 10; the largest peasant pastoral producers owned 60 sheep alongside numerous other livestock (Hilton 1966, pp. 107-8). In 1337, three peasants were fined on the Worcestershire manor of Overbury for grazing 400 sheep on the landlord's common; the normal number of sheep per peasant in such trespasses was 12 (Hilton 1966, p. 109). In Lakenheath in Suffolk in the 1340s, tithe evidence reveals that peasants owned 2,340 sheep, compared with the manorial lord's flock of 2,280 (Bailey 1989, pp. 246, 250).

On the eve of the Black Death, many landlords kept cows, but few tended to them directly or turned their milk into dairy produce. Instead, they leased cows individually to local peasants, who paid an annual sum for 'lactage' (the milk and dairy products produced from the animals' lactation), and the peasant household supplied the labour required for calving, milking, butter-churning, cheese-making, and marketing; as we discuss in the main text and in Section A4 below, much of this labour was provided by married peasant women. Peasants hired these demesne cows from landlords to supplement their own stocks, a practice that can be observed at latest by the 1290s. The variations in the rates paid for lactage, together with the varying proportions of cows among all demesne cattle, reveal that in many areas of eastern and southern England peasant dairy production was highly intensive and commercialized (Campbell 1992, p. 113-14; Campbell 1995, pp. 291-4; Campbell 2000, p. 146; Bailey 2007, pp. 81-4).

After the Black Death, labour costs rose, grain prices fell, and prices for meat, milk, cheese, and wool rose. Pastoral agriculture required only one-fifth of the labour per unit land needed for arable cultivation (Campbell 2000, p. 10). Peasants responded to these price-signals by shifting from arable to pastoral production (Mate 1987, p. 525, Dyer 2005, pp. 129, 169). Having found no references before 1349 to Warwickshire peasants with more than 10 cattle or 100 sheep, Dyer (1981, p. 30) found greater peasant livestock ownership at the end of the fourteenth and throughout the fifteenth century, with various examples of individual peasants owning 20 beasts, 23 beasts, 60 cattle, 26 oxen, 16 cattle, 15 cattle and 6 horses, 300 sheep, and 360 sheep. In Berkshire, according to a Feet of Fines, a documentary source which recorded mainly non-demesne (i.e. peasant) land, the proportion of pasture rose from 6% before 1349 to 41% in the early fifteenth century (Yates 2012, p. 150). In Gloucestershire, pasture rose from 2% of the total around 1300 to 18% in the early fifteenth century on the Cotswolds, and from 1% to 14% in the Vale of Gloucester (Dyer 2016, p. 82).

One specific way in which peasants expanded their pastoral activities was by leasing pastures from landlords (Dyer 1981, pp. 4-5; Watkins 1989, p. 18). Such leases already occurred in the early fourteenth century, but proliferated rapidly after the Black Death, so that

by c. 1450 most landlords had abandoned direct exploitation of their demesnes (Lomas 1978, pp. 339-40, 345, 352; Campbell 2000, pp. 3, 58-60; Dodds 2008, p. 77). As a result, more peasants obtained access to grazing and began to raise livestock and engage in pastoral activities (Bailey 1989, pp. 257-8; Watkins 1989, p. 19; Campbell 1992, p. 113; Bailey 2007, pp. 220-1; Hare 2011, pp. 78-9, 101-5). Some of the peasants who leased demesne land after the Black Death became large-scale producers, and thus can no longer be described as peasants, although they still leased rather than owned the land they worked. These large-scale lessees, who were described as 'farmers' by contemporaries, cannot be easily fitted into conventional social categories (Dyer 2005, pp. 194-5, 207). On fourteen Wiltshire manors, however, at least 39% of fifteenth-century demesne lessees were drawn from the ranks of local customary tenants, i.e. the peasantry (Hare 2011, p. 101). Moreover, demesnes were often leased to multiple lessees rather than just one, in which case the peasantry were invariably involved (Dyer 1981, pp. 4-5). Among 75 Warwickshire demesnes that were leased between 1365 and 1511, 12 were leased in this way, three of them to all the tenants of the manor collectively, i.e., to all the local peasants (Dyer 1981, p. 5).

The fact that so many landlords leased animals and pasture to so many peasants over long periods suggests that both parties believed that peasants would exploit those assets more productively (Campbell 1992, p. 114; Campbell 2000, pp. 146-7). The high rentals paid by peasant lessees of landlord cows, both before and after the Black Death, 'testify to the potentially greater intensity and productivity of peasant as opposed to demesne husbandry' (Campbell 1992, p. 113). In sheep-raising, as well, peasants were more productive than landlords, with peasant sheep-farmers achieving lambing rates and subsequent survival quotients superior to those in demesne herds (Stone 2003, p. 21; Dodds 2008, p. 85). Overall, medievalists regard small peasant farmers as having been more proficient practitioners of pastoral technology than large landlord estates because of lower costs of administration and management, superior local knowledge, better monitoring and supervision of animal well-being, and greater use of highly motivated family labour (Hare 1981, p. 14; Britnell 2008a, p. 29).

VV's assumption that the technology of pastoral production was only available to the landlord does not therefore reflect the historical reality. An alternative assumption which would yield similar results is that pastoral production required a minimum amount of land (VV 2013, fn. 27 p. 2238). If such a minimum scale existed, clearly it did not rule out pastoral production by numerous peasants, as is shown by the evidence discussed above. However, it might be argued that peasant pastoral output made up only a small share of total

pastoral production. If so, most pastoral output would have been produced by owners of large estates, and the growth in female pastoral work after the Black Death would have mostly been in landlord production. Under such circumstances, VV's assumption of a minimum land requirement for pastoral agriculture would be an acceptable simplification.

But there is overwhelming evidence that this assumption, too, is inaccurate. Peasants produced a majority of agricultural output in England – perhaps 60-80% – before the Black Death, and an even higher proportion thereafter (Campbell 2000, p. 56). In Worcestershire between 1273 and 1320, for instance, the landlord demesne comprised about 30% of the median value of a manor, with tenants (the peasant sector in the VV model) farming the other 70% of land by value (Dyer 2016, p. 65).

Peasants also produced most of the output in the pastoral sector. This was true even in sheep-raising which was by far the most land-intensive pastoral enterprise and thus most suited to large landlord operations: the best available estimate indicates that throughout the 1250-1450 period the landlord share of the national sheep flock 'must have been substantially smaller than its share of the national arable area' (Campbell 2000, p. 159). In Suffolk as early as the 1280s, stocking densities of sheep were higher on peasant farms than on the landlords' demesnes and peasants supplied six times as much wool as landlords (Slavin 2015, pp. 10, 22). In the century after the Black Death, non-demesne (i.e. mainly peasant) sheep flocks 'must have formed a large proportion of the total ovine population of England' (Stone 2003, p. 21). Peasants predominated in the raising of cows, as well. Stocking densities for cows were higher on peasant holdings than on large landlord estates in Suffolk in the 1280s (Slavin 2015, p. 10, 14). After the Black Death, even more of the cow population of England moved into peasant hands, with the rents from leasing demesne dairy herds to peasants comprising the single greatest contribution to the increase in seigniorial money revenues in the period after c. 1350 (Campbell 2000, p. 435). Commercialized dairy production increased markedly after the Black Death on many peasant holdings in Suffolk in response to increased per capita consumption of dairy products among the lower orders of society (Bailey 2007, pp. 219-26). Commercial poultry rearing also shifted from the demesne to the peasant sector, mainly because the high costs of tending geese and chickens were more readily absorbed within peasant households in an era of labour shortages (Slavin 2010, pp. 9-15, 26).

The aggregative evidence confirms that peasants produced at least as much wool as large landowners in medieval England, even before the Black Death. In the early fourteenth century, England exported about 30,000 sacks of wool in a typical year. Bridbury (1977, pp 398-9), Masschaele (1997, pp. 52-3), and Campbell (2000, pp. 158-9) have calculated how

much of this could possibly have been produced by large landowners. Masschaele, for example, estimates that ecclesiastical estates produced no more than an average of 5,000 sacks annually. Lay estates are less well documented, but Masschaele regards 8,550 sacks annually as an upper bound. Over half the annual English wool exports of about 30,000 sacks in the early fourteenth century was therefore produced by peasants. Assuming that domestic wool consumption amounted to 25% of the quantity exported, then peasants produced almost 65% of English wool (Masschaele 1997, pp. 52-3). Bridbury (1977) and Campbell (2000) provide somewhat different estimates, but also conclude that peasants produced a very substantial share of the wool sold in medieval England.

The pastoral output produced by each individual peasant before the Black Death was indeed small, but there were nearly a million peasant holdings and only 20,000 landlord demesnes.[1] For this reason, peasants kept most of the cattle and pigs as well as most of the sheep in late-thirteenth-century England (Dyer 2005, p. 89). The evidence produced by economic historians of medieval England clearly rejects any claim that peasants were unimportant in pastoral agriculture before the Black Death because they operated on a very small scale.

A4. Women and pastoral production in the peasant household

What about the work of women on the peasant holding? It might still be argued that, although peasants engaged in pastoral production, once peasant women were married they helped their peasant husbands in arable production, but did not engage in pastoral production. This is the argument of the VV model, and is crucial to their conclusion that the shift to pastoral agriculture caused women to refrain from marriage until they reached a more advanced age. However, the historical evidence does not support this assumption. Married

[1] The 20,000 figure is calculated as follows. Campbell and Bartley 2006, pp. 314-15, give a figure of 14,441 vills from early-fourteenth-century tax lists. This should be rounded up to c. 15,000 to allow for two counties that were not included because they were tax-exempt. The best count of manors and vills in medieval England is provided by Kosminsky 1956, who on pp. 74, 97, reports that 784 vills contained 1,071 manors, implying that each vill had 1.32 manors. This yields a national total of 19,800 manors on the c. 15,000 vills in England. The estimate might be slightly increased by taking into account the hundreds of larger rectories which were funded from "rectory manors" with demesnes and employees. Conversely, the estimate might be reduced by omitting some hundreds of manors in the far north and south west which were mainly pastoral. The estimate might also be reduced by taking into account the fact that 65% of manors were small, i.e. 500 acres or less (Kosminsky 1956, p. 98). A plausible assumption is that about one-third of these, i.e. c. 20% of all manors, were so small as to provide very little employment. We are very grateful to Chris Dyer for his expert advice on these estimates.

women did work in the pastoral sector in medieval and early modern England, both in peasant pastoral production and as paid labourers for landlords.

The work of married women, particularly among the peasantry, is among the least visible in the historical records (Wall 1994, p. 139; Ogilvie 2003, p. 140). It is thus striking that the surviving evidence on the work of peasant wives in medieval England confirms unambiguously that they did not just engage in housework but also made a substantial contribution to the agricultural work of the peasant household. This included pastoral activities since, as discussed in Section 3.1 of the main text and in Section A3 above, virtually all peasant holdings practised mixed agriculture and shifted towards more pastoral production after the Black Death. Power's classic account, for instance, states uncompromisingly that medieval peasant women 'were expected, if they were married, to share in all their husband's labours on their family holdings' and describes 'the strenuous hours and weeks which a working wife was called upon to spend by her husband's side in fields and pastures' (Power 1975, p. 71). Manorial accounts and court records show that 'even married women with young families did venture from their homes' (Goldberg 1991, p. 82). These sources reveal that 'women participated in most aspects of agrarian life whether as family labour or paid employees'; the only jobs they are not recorded doing are ploughing and mowing, both arable tasks (Goldberg 1992b, p. xii).

Married women in medieval and early modern England performed many of the same forms of work as those for which they had received wages as unmarried servants (Mendelson and Crawford 1998, p. 269). Since women were particularly productive at pastoral work when they were servants, it is unsurprising that they also specialized in animal care when they worked as married women within the peasant household enterprise. Twelfth- and thirteenth-century English peasant housewives, for instance, 'took care of the family's cows, pigs and poultry as well as the crops growing in the garden' (Mate 1999, p. 16). Analyses of the seasonality of married women's work inside the peasant household suggests that 'spring was an exceptionally busy time for women ... this would have been most true of pastoral regions' (Goldberg 1991, p. 81).

The peasant housewife bore main responsibility for all animals except the oxen or horses used to draw the plough. Married peasant women were responsible for the daily care of the cows and sheep which, as we have seen, many peasant households kept in large numbers. The peasant housewife fed the animals, weaned the young calves and lambs, milked the cows and ewes, made butter and cheese, and participated at calving and lambing (Hanawalt 1986a, pp. 1, 10; Hanawalt 1986b, p. xiv; Holderness 1990, p. 264; Goldberg

1991, p. 82; Graham 1992, p. 127; Mate 1999, pp. 31-2; Bardsley 2007, pp. 63, 66). In peasant households nearly everywhere in England, 'wives raised pigs and poultry to provide food for the households ... milked cows and ewes and manufactured butter and cheese ... In the period after 1348 this work outside the home became even more important' (Mate 1999, p. 31-2). Medieval court records describe peasant housewives engaging in dairying operations such as milking cows (Goldberg 1992a, p. 110). Medieval coroners' reports show peaks in peasant women's accidental deaths in the morning and at noon, resulting partly from women 'working with large animals' (Hanawalt 1986a, p. 8). In a famous sermon, Bishop Hugh Latimer (born 1487), described how his farmer father 'had a walk for a hundred sheep, and my mother milked thirty kine' (quoted in Du Boulay 1965, p. 451). Milking and dairying were exclusively female occupations in medieval England and continued to be so throughout the early modern period (Whittle 2005, p. 69).

Married peasant women cared for cows, sheep, and pigs during the winter when they were penned outside, sheltered in byres, or (as in some northern and western regions) housed under the same roof as the peasant family. In the other seasons of the year, peasant wives were responsible for taking the animals to pasture and herding them in the environs of the village (Hanawalt 1986a, p. 9; Bardsley 2007, p. 66). The daily routine of the peasant housewife involved driving the cows to pasture and taking the geese to the green (Hanawalt 1986a, p. 9). Medieval law-courts record peasant women being prosecuted 'for illegally trespassing with animals in the common field' (Graham 1992, p. 129). Married peasant women appeared in manor courts accused of offences relating to herding animals, as in 1331 when a married woman in Wiltshire was punished for taking her cow out of the landlord's pinfold where it had been placed (Müller 2013, p. 106). Pastoral production was sufficiently central to the responsibility of peasant wives that in 1403 a woman in Bothall bequeathed a cow apiece to two married women serving her in her final illness (Goldberg 1995, p. 179).

Surviving archival documents include a number of cases in which adult peasant women of unrecorded marital status are described as operating in the pastoral sector with their own animals, as in 1383 when a woman in Middlesex entered a man's land 'with her pigs and destroyed his corn within his close, viz. beans and peas to the damage of ... 3s. 4d.' (Goldberg 1995, p. 174). We cannot be sure that such women were currently married: they may have been widows or independent spinsters. However, the women in these cases are clearly working in peasant (i.e. non-landlord) pastoral production as independent adults rather than servants or offspring. Given the archival references to married peasant women doing

pastoral work, it seems certain that some of the adult peasant females of unknown marital status recorded as working in the pastoral sector were married women.

The peasant housewife was also involved in the purchase, washing, and shearing of the sheep in the household flock. In court records from medieval rural communities, married peasant women are observed purchasing sheep (Goldberg 1992a, p. 110). The peasant housewife and the resident daughters of the family are described as washing and shearing the sheep owned by the peasant enterprise (Bardsley 2007, p. 66). Manorial court records describe married women as 'clipping sheep in the pasture for their wool' (Hanawalt 1986a, p. 13).

Married women were also intensively involved in the marketing of pastoral goods produced by the peasant household. Thus it was the peasant housewife who sold the pastoral surplus – eggs, butter, cheese, yarn – in the local market or the neighbouring town (Goldberg 1991, p. 82; Mate 1999, pp. 31-2; Dyer 2005, p. 28, 89). Married peasant women are described as having control over the money they earned by selling these pastoral products (Hanawalt 1986a, p. 16). In the more detailed archival sources of the sixteenth and seventeenth centuries, farmers' wives are recorded engaging in specialized dairying operations, in which they would churn cream into butter on Tuesdays and Fridays ready to take it to sell at the markets customarily held on Wednesdays and Saturdays (Mendelson and Crawford 1998, p. 307). The activities of medieval peasant housewives in producing and marketing pastoral goods are regarded as having afforded them 'some independence of action, and a very real degree of economic clout within the family economy' (Goldberg 1991, p. 82; see also Mate 1999, pp. 33-49).

The historical evidence does not, therefore, support the assumption that medieval women only engaged in pastoral production if they worked for landlords. Not only did medieval peasant households engage in a great deal of pastoral production, but peasant housewives were fully involved in this work, and their involvement almost certainly increased with the shift from arable to pastoral after the Black Death. Married peasant women performed many of the same types of work as those for which they had received wages as unmarried servants, specifically the pastoral tasks in which female productivity was high. The implications for marriage patterns are clear. Since medieval English peasant households engaged in pastoral production, and did so increasingly from 1350 onwards, women could work in the pastoral sector on the peasant family holding and did not need to work for a landlord. Women did not have to remain unmarried in order to work in pastoral agriculture, even if it were the case that working for landlords required women to stay single.

A5. Married women's employment on landlord estates

Medieval economic historians have devoted considerable attention to finding out as much as possible about the paid agricultural labour force, including the participation of females, despite the paucity of detailed archival sources recording such work. The findings of this literature are important for examining a further crucial assumption in the VV theoretical model, namely that women who worked for a landlord had to do so as unmarried agricultural servants. The VV model assumes that the agricultural labour force consisted of unmarried live-in servants working for landlords and members of peasant households working for themselves. This ignores the rich evidence presented by medieval economic historians documenting the existence and activities of a third substantial group of workers: independent labourers, comprising individuals of both sexes and a range of marital statuses, including married women. In the late fourteenth century, a typical English landlord would employ between four and ten full-time farm servants, but between one dozen and two dozen labourers (Dyer 2005, p. 229). The Cheshire estate of Newton in 1498-1520 combined animal husbandry (cattle, sheep, pigs and hens) with crop growing, employing a labour force of approximately five workers at any given time, made up of resident servants, long-term non-resident labourers, and short-term day-labourers, of both sexes (Youngs 1999, pp. 146-8).

Wage-labourers were recruited from the under-employed male and female members of smallholder and cottager households who did not have access to sufficient land to live wholly from farming. In such households, both the husband and the wife often had to take work as wage-labourers for landlords (Middleton 1979, pp. 159-62; Hanawalt 1986a, p. 11; Bardsley 2007, p. 63). Married peasant women frequently engaged in work that was not an integral part of the peasant household but instead involved selling their labour on the market to employers (Smith 1990b, p. 53). As a result, the work profile of women married to wage-earning men 'was not so dissimilar from that of many single women' (Goldberg 1986a, p. 34).

If anything, independent labouring by married females intensified after the Black Death. Dyer describes an increase in the labour-force participation of married females, as rising wages pulled increasing numbers of wives who had previously engaged in unpaid household work into wage-earning market employment (Dyer 2005, pp. 222-3). Bailey argues that the Black Death caused a widespread shift from servanthood by unmarried individuals to wage-labouring by married couples: both sexes married at an early age but

supplemented family incomes by wives taking wage-labour where necessary (Bailey 1996, pp. 13-5). This was understandable: in conditions of labour scarcity, workers were less attracted by guaranteed servanthood contracts since they knew they could get steady work as labourers, at higher wages than if they worked as servants (Bailey 1996, p. 14). It was also easier for employers and the authorities to enforce wage ceilings and mobility restrictions against servants on annual contracts than against casual day-labourers (Humphries and Weisdorf 2015, pp. 420-3). Labouring may have been particularly attractive for female workers since, as discussed in the main text, female labourers' wages rose after the Black Death whereas female servants' wages stayed remarkably flat, possibly because unmarried maidservants were more vulnerable to employers' enforcement of the legal wage ceilings (Humphries and Weisdorf 2015, pp. 417, 420-3).

Females – including married women – certainly made up a non-trivial proportion of English labourers in the period after the Black Death. In Somerset in 1358-60, females comprised 26% of those described as 'labourers' who were punished for charging wages higher than the legal wage-ceiling (Penn 1987, pp. 506). In Essex in 1352, 1,559 female labourers were prosecuted for such violations, and over 15% of these women were explicitly described as married (Poos 1991, p. 226). On the Essex demesne of Porter's Hall in 1483-4, approximately one-third of all person-days worked by labourers were worked by females; of the sixteen named female labourers, six were explicitly described as married (Poos 1991, pp. 214, 217). On the Cheshire estate of Newton in 1498-1520, 14 of 45 female day-labourers (31%) were specifically recorded as married women and a number of others shared surnames with male workers and may therefore have been married to them (Youngs 1999, pp. 157-8). Marriage may even have helped women get work as labourers. For one thing, married females were not subjected to the social and legal pressures placed on unmarried ones to enter into dependent annual servanthood contracts. For another, wives often obtained access to employment through husbands, worked alongside them, or were recruited by them to work for the same employer (Penn 1987, pp. 6-11; Youngs 1999, pp. 157-8; Humphries and Weisdorf 2015, pp. 411-2).

Documentation of the precise tasks carried out by married female labourers is extremely rare, even after 1500 when archival sources become more plentiful. Unsurprisingly, however, the few surviving references show that the work of married female labourers included the normal pastoral tasks in which females engaged as unmarried servants and as peasant housewives (Mendelson and Crawford 1998, pp. 273-4). In 1483-4, a married woman was paid wages for doing twelve days' milking at Porter's Hall in Essex (Poos 1991,

p. 217). In a Devon village in 1598, a married woman was being paid to shear sheep; in a Somerset village in 1603, a work gang shearing sheep for wages consisted of three men and two married women (one working independently of her husband); in another Devon village in 1634 two married women aged 53 and 54 were working as hired labourers and 'deposed that they had together sheared 50-60 sheep in each of the last three years for one Westcott of Holcombe Burnell'.[2] Availability of archival sources means that most examples explicitly stating that married female labourers worked in pastoral activities come from the period after c. 1480, but there is no reason to believe that the many married female labourers recorded in earlier medieval documents did not also earn their wages doing pastoral tasks, especially given the evidence discussed earlier showing that married women carried out pastoral work within the peasant household.

A second pattern was for married women to be employed by landlords to do pastoral work at a higher level of responsibility. In the thirteenth century, the De Lacy estate in Lancashire ensured the management of its pastoral enterprises by hiring married vaccary keepers who organized the labour force to care for the livestock using their entire households: men, wives, children, and hired herdsmen. The wives and other female family members were responsible for the milking, the butter-churning, the cheese-making, the other dairy work, and the marketing of the produce. When the herds were moved seasonally, the wives and daughters of the vaccary keepers remained at the home farm to tend the milk-cows and calves and do the specialized cheese-making. So fully involved were the vaccary keepers' wives in this paid pastoral work for landlords that in the 1290s three of the De Lacy vaccaries were operated by women, probably widows who had previously been running them with their husbands and were holding the tenancies until sons could take over (Atkin 1994, p. 16). Similar family-based pastoral employment of married women in the pastoral sector is recorded in other contexts, as on the Sussex manor of Alciston which in the fifteenth century employed married male shepherds and dairymen who carried out their paid employment with the aid of their wives and other family members (Mate 1999, p. 32). In 1509 the East Suffolk manor of Sibton Abbey employed a married woman called Katherine Dowe to manage the demesne dairy. With the help of three maidservants, she was responsible for caring for 63

[2] Devon quarter sessions 1598 (Devon Heritage Centre, QS/4/Box5); Somerset church court deposition 1603 (Somerset Archives, Church Court Depositions D/D/Cd/36); Devon church court deposition 1634 (Devon Heritage Centre, Chanter 866). We are very grateful to Jane Whittle for her generosity in providing these references.

cows, milking them, manufacturing the butter and cheese, and caring for the pigs and poultry (Whittle 2005, pp. 69-70).

The historical evidence does not, therefore, support the assumption that working for a landlord in pastoral production required a woman to remain unmarried. On the contrary, many land-poor and landless rural households could not survive unless both the husband and the wife went out to work, often as wage-labourers for landlords. Females in general, and married women in particular, made up a quantitatively significant share of the agricultural labourers employed by landlords and better-off farmers. Although the precise tasks performed by such married female labourers are only rarely recorded, they clearly included pastoral as well as arable work. Married women also worked for landlords in positions of greater responsibility, both as partners in familial teams of vaccary keepers and as individual managers of demesne dairy operations. The key assumption in VV's theoretical model, that women had to remain unmarried in order to do paid pastoral work for landlords, is thus not consistent with the historical evidence.

A6. What does the proportional drop in taxpayers between 1377 and 1381 measure?

VV argue that the proportional decrease in the number of taxpayers in a county between the 1377 and 1381 poll tax returns is an acceptable proxy for the proportion of unmarried women in English counties in 1381. They use this measure to claim that there is evidence of a positive causal relationship in 1381 between the share of pastoral land in a county and the proportion of unmarried women there, in line with their theoretical model.

VV's theory is actually formulated in terms of a relationship between pastoral land and the proportion of never-married women of fertile age (henceforth never-married fertile women). However, in their empirical work, VV use 'unmarried women' to refer to a mixed group that includes spinsters beyond child-bearing age and widowed females as well as never-married fertile women. In what follows, we refer to this larger group as 'not-currently-married women' in order to avoid confusion. For obvious reasons, the proportion of not-currently-married women does not enable a direct test of VV's theory, since only an unknown subset of this group were never-married and of fertile age, and could thus affect fertility. However, for the reasons discussed below, the proportional fall in the number of taxpayers between 1377 and 1381 is not even an adequate proxy for the proportion of not-currently-married women, let alone the proportion of never-married fertile women.

The 1377 poll tax required a payment of 4 pence per head from all lay men and women aged 14 or over who were not genuine paupers. The 1381 poll tax was imposed on all lay men and women aged 15 or over who were not genuine paupers, requiring them to pay a graduated, wealth-dependent sum whose average value was 12 pence (one shilling) per head, such that the total revenue in shillings collected from a vill was equal to the number of taxpayers in the vill (Fenwick, 1998, pp. xiv, xvi). Many fewer taxpayers were recorded in 1381 than in 1377. One reason is that the 1377 tax included, while the 1381 tax excluded, 14-year-olds. The total population in 1381 was also slightly lower than in 1377: Broadberry et al. (2015, Table 1.04) suggest that it fell by about 3% over these years. But the drop in the number of taxpayers from 1377 to 1381 is too large to be explained by these considerations.

VV's use of the proportional drop in the number of taxpayers in a county between 1377 and 1381 as a proxy for the proportion of never-married fertile women in that county in 1381 is based on Oman's argument that the number of taxpayers fell because of the concealment in 1381 of 'the existence of ... unmarried female dependents, widowed mothers and aunts, sisters, young daughters, &c.' (Oman 1906, p. 28). If never-married fertile women had been the only group under-recorded in 1381, the proportional drop in taxpayer numbers would be a reasonable proxy for the share of these women in the population, and thus of nuptiality in a county. But this is not the case.

As the quotation above shows, Oman thought that widows as well as never-married fertile women were under-recorded in 1381. In EMP populations from early modern England, widows comprised about 25% of not-currently-married females aged 15 and over, and never-married females beyond fertile age comprised another 3% (see section A7 below). If England was an EMP society in 1377-81, this implies that, even if the drop in taxpayers was entirely female, only about 72% of it would have consisted of never-married females of fertile age, the demographic group for which a proxy is needed.

However, the fall in the number of taxpayers between 1377 and 1381 was not entirely female. On the basis of the 1381 Gloucestershire returns, Hilton notes that 'there was in some places a massive concealment of servants, not, as Oman concluded from the Essex evidence, of unmarried females' (Hilton 1975, p. 32). Servants were typically adolescents of both sexes, and '[w]hereas there is no preponderance of either sex in the servant group as a whole within many larger towns, male servants tend to outnumber female in the countryside' (Goldberg 1990, p. 212). Many of the servants under-recorded in 1381 were thus young men rather than young women, making the proportional drop in taxpayer numbers an even worse proxy for the proportion of never-married fertile women. Because the gender composition of

those under-recorded varies among counties, the error involved in using the proportional drop in taxpayer numbers as a proxy for the proportion of never-married fertile women will also vary by county. It cannot therefore be argued that the former is a reasonable proxy for the latter on the grounds that the error in so doing is the same across counties.

Fenwick (1998, pp. xxiii-xxvi) argues convincingly that it was primarily the poor who were under-recorded in 1381. Genuine paupers were exempt from the tax, which was assessed during one of the worst winters in memory, at a time when no seasonal work was available, and after a particularly bad harvest. Thus there must have been many more individuals who could legitimately be described as genuinely poor in 1381 than in 1377, when the tax was assessed and collected at a time during which seasonal work was available. Furthermore, the 1370s were a decade of intense taxation after a period of 14 years in which no tax had been imposed. Thus some people who paid the poll tax in 1377 could not do so in 1381 because of the heavy tax burden in the 1370s, and hence were legitimately exempt. Finally, everyone (except the Crown) had an incentive in 1381 to minimise the recorded number of taxpayers, because, in contrast to the 1377 tax, the 1381 tax required vills to pay the same number of shillings as there were taxpayers, with the rich paying more than the poor. The assessments of the rich would increase with every low-income taxpayer, so both rich and poor had an incentive to minimize the number of such taxpayers by treating them as genuine paupers, who were not recorded.

Fenwick's interpretation is consistent with there being substantial under-recording of both not-currently-married women and not-currently-married men, since these groups were more likely to have low incomes, even if they were not genuine paupers. But the low-income group also included married couples who owned little land or worked as labourers. The proportional drop in the number of taxpayers between 1377 and 1381 thus comprised an unknown mixture of poor not-currently-married women, poor not-currently-married men, and poor married people of both sexes.

That this must have been the case emerges clearly from examining the size of the proportional fall in county-level taxpayer numbers used as the dependent variable in the regressions reported in VV Table 3. To allow for the 3% fall in total population 1377-81 and the exclusion of 14-year-olds in 1381, we adjusted VV's estimates of the proportional fall between 1377 and 1381. We did so by assuming that, in the absence of any other changes, the fall in the population and the different definition of the tax base in 1381 would have resulted in the number of taxpayers in each county in 1381 being 5% lower than the number of

taxpayers in 1377.[3] Based on this assumption, we then calculated an adjusted proportional fall in taxpayers between 1377 and 1381, which allows for the estimated 5% reduction that would have occurred between these dates even in the absence of any under-recording. For the 38 counties used in VV's analysis, the mean value of this adjusted proportional fall is 30.0% and the median is 27.3%. The evidence available for EMP populations in early modern England suggests that on average roughly 20% of the population comprised never-married fertile women and roughly 8% were widows and never-married women beyond fertile age (see Section A7 below). Assuming that late-fourteenth-century England was an EMP population characterised by similar proportions, it follows that, if the mean fall in adjusted taxpayer numbers of 30% were to be explained solely by under-recording of not-currently-married women in 1381, it would require essentially all not-currently-married women to be excluded from the 1381 returns. But the 1381 returns actually included a non-trivial proportion of such women. On average, therefore, in order to explain the mean value of the observed proportional drop in taxpayer numbers, some under-recording of groups other than not-currently-married women must have taken place.

Not-currently-married men are one such group. But under-recording of married people is also required in order to explain the observed fall in taxpayer numbers, at least in some cases. In five of the 38 counties, the adjusted proportional drop in taxpayer numbers was greater than 50%. On average, roughly 21% of EMP populations in early modern England consisted of not-currently-married men, and roughly 52% consisted of married people (see Table A1 in Section A7 below). Assuming that these proportions prevailed in late-fourteenth-century England, the exclusion of all not-currently-married people from the 1381 returns would not be enough to explain the drop in taxpayers in these five counties. There must, therefore, have been some under-recording of married people. Since not-currently-married people are in fact recorded in non-trivial proportions in the 1381 returns, it follows that more than five counties must have under-recorded married people. In a further six counties, the adjusted proportional drop in taxpayer numbers was 40-50%. Given that some of the roughly 48% of not-currently-married persons were actually recorded in the 1381 returns, declines of 40-50% are also difficult to explain in the absence of some under-recording of married persons.

[3] In English census-type listings from the early modern period, when the EMP definitely prevailed, 14-year-olds comprised 2.3% of the population (see Section A7 below).

The proportional drop in taxpayer numbers between 1377 and 1381 is not, therefore, an adequate proxy for the proportion of never-married fertile women, a measure of which is needed in order to test VV's theory. VV's attempts in pp. 18-23 of their Appendix to justify their use of this measure as a proxy for the proportion of never-married fertile women are based on the assumption that there was no under-recording of not-currently-married men in 1381, but this assumption must be incorrect, as we have seen.

A7. Age- and gender-specific marital status in English EMP populations

No census-type listings recording age- and gender-specific marital status survive for medieval England. Consequently, the figures presented in Section A6 on the percentage of an EMP population that is never-married, currently married, or widowed in different age-groups and gender-categories are derived from census-type listings dating from the early modern period (the sixteenth, seventeenth, and eighteenth centuries), when the EMP certainly prevailed.

Most English census-type listings before the nineteenth century do not record ages, but eleven surviving listings do so. In date order, these are the listings for Ealing 1599, Grasmere 1683, Chilvers Coton 1684, Lichfield 1695, Buckfastleigh 1698, Ringmore 1698, Stoke-upon-Trent 1701, Cardington 1728, Wembworthy 1779/80, Corfe Castle 1790, and Ardleigh 1796. With the exception of Lichfield, all eleven settlements were villages at the time of enumeration, with a mean size of 958 inhabitants. Even Lichfield had only 2,861 inhabitants in 1695 and thus, although urban, was small. These eleven settlements, covering the period from the late sixteenth to the late eighteenth century, provide the earliest surviving evidence on age- and gender-specific marital status in English rural settlements under the EMP.

Table A1 reports statistics on marital status by age and sex in the entire sample of eleven settlements, 'England 11', together with two sub-samples, 'England 10' and 'England 2'. 'England 10' is presented because Statistics 1, 5 and 6 cannot be calculated for Buckfastleigh, Devon, 1698, whose listing does not record the required information. However, Statistic 1 has been deduced for 'England 11' by subtracting Statistics 2-4 from 100%. 'England 2' is presented because Statistic 7 can only be calculated for two settlements (Ealing 1599 and Stoke-upon-Trent 1701) whose censuses have been published in full, making it possible to count the number of individuals aged 14.

Table A1. Marital status by age and sex in early modern England

Demographic statistic	England 11	England 10	England 2
1. Never-married fertile women (i.e. aged 15-49) as % of total population aged 15 or above	[18.5]	20.3	18.8
2. All widows of any age + never-married women above fertile age as % of total population aged 15 or above	8.4	8.0	8.6
3. Not-currently-married (never-married + widowed) men as proportion of total population aged 15 or above	20.8	20.9	23.2
4. Married persons of both sexes as % of total population aged 15 or above	52.3	51.6	49.4
5. Widows as % of not-currently-married females aged 15 or above	n/a	25.2	27.8
6. Never-married women over aged 49 as % of not-currently-married females aged 15 or above	n/a	3.1	3.7
7. Persons aged 14 as % of total population	n/a	n/a	2.3
Total population of all settlements combined	10,537	9,420	2.054
Average settlement size	958	942	1,027

Notes: "England 11" = Ealing 1599; Grasmere 1683; Chilvers Coton 1684; Lichfield 1695; Buckfastleigh 1698; Ringmore 1698; Stoke-upon-Trent 1701; Cardington 1728; Wembworthy 1779/80; Corfe Castle 1790; Ardleigh 1796. “England 10” = all the above settlements excluding Buckfastleigh 1698, whose listing does not record the information required to calculate Statistics 1, 5 and 6. Statistic 1 is calculated for “England 11” by subtracting Statistics 2-4 from 100%. “England 2” = Ealing 1599 and Stoke-upon-Trent 1701, the only settlements whose censuses have been published in full, enabling calculation of Statistic 7.

Source: “England 11” and “England 10” calculated from CAMPOP B(B), Binders 2, 5, 6, 8, 17, 20, 21, 22, 24. “England 2” calculated from CAMPOP B(B), Binders 17 & 21; together with Allison 1963 (full census for Ealing 1599); Gatley et al. 1996 (full census for Stoke-upon-Trent 1701).

A8. Discussion of regression variables

The dependent variable in VV's Tables 4 and 5 is derived from the Cambridge Group for the History of Population and Social Structure estimates of female age at first marriage (FAFM), which are available for a maximum of 26 parishes at five different periods (1625, 1675, 1725, 1775 and 1819).[4] The dependent variable is the mean FAFM in the parishes located in a particular county, observed at five different periods. Although FAFM varies across periods, two of the three pastoralism regressors take the same value in all five periods. The exception is the share of parishes with spring marriage seasonality, as will be discussed shortly.

The two pastoralism regressors in VV's Table 4 both raise measurement issues. *Pastoral 1290* is constructed as one minus the proportion of arable land in a county in 1290 as estimated by Broadberry et al. (2015, Table 2.07, pp. 66-7). This is only an approximation of the actual proportion of pastoral land, since non-arable land also included woodland, unfarmable moorlands and mountains, ornamental parks, surface water, communications, and settlements. The precise composition of non-arable land thus varied across counties. In their online appendix, VV provide reasons for regarding the proportion of non-arable land as a reasonably accurate indicator of the proportion of pastoral land. However, it unavoidably measures the share of pastoral land in 1290 with error and this error almost certainly varied across counties.

DMV, the county-level number of deserted medieval villages per 100,000 acres, is obtained from Broadberry et al. (2015, Table 2.05), who in turn construct it using information about deserted villages from Beresford (1989). VV interpret this variable as a proxy for the post-Black-Death shift from arable to pastoral production. However, such an interpretation is untenable. Some villages that were deserted in the fifteenth century either reverted to wasteland or saw their fields continuing to be used for arable agriculture by peasants from neighbouring villages (Dyer 1982, pp. 29-30). Village desertion did not invariably reflect a shift to pastoral: in many parts of England the existence of such villages 'probably reflects little more than the effects of the declining population and associated settlement change, and there may have been little or no enduring loss of land to arable production' (Broadberry et al. 2015, p. 58).

Furthermore, *DMV* measures post-Black-Death village desertion with considerable error. These villages did not all become deserted in the century after the Black Death: some were

[4] FAFM was available for 19 of the 26 villages in 1625, 21 in 1675, 26 in 1725, 24 in 1775, and 22 in 1819.

deserted soon after 1086, others only after c. 1700 (Beresford 1989, Table II). Probable desertion dates are known only for four counties, ones with comparatively high *DMV* values. In these counties, 8% of villages became deserted in the period c. 1086 – c. 1350, 19% c. 1350 – c. 1450, 59% c. 1450 – c. 1700, 6% after c. 1700, and 9% at an unknown date. *DMV* is therefore an indicator of villages becoming deserted not in the century after the Black Death, but over a very much longer time span. Only about one-fifth of villages of known desertion date became deserted in the century after the Black Death.[5] The incentives to convert arable into pastoral were strong between c. 1380 and c. 1500, so some villages that became deserted between c. 1450 and c. 1500 probably reflected the long-term effects of the Black Death. But there were also strong incentives to convert arable to pastoral after c. 1650 (Broadberry et al. 2015, pp. 60-1), so some of the villages used to construct *DMV* reflect a distinct phase of conversion from arable to pastoral some three hundred years after the Black Death. As a result, *DMV* not only measures the shift from arable to pastoral agriculture with error, but is also a bad control, since the shift to pastoral after c. 1650 was probably influenced by some of the factors affecting FAFM during that period, so *DMV* is an outcome variable in the notional experiment at hand.[6]

The pastoralism regressor in VV's Table 5 also raises measurement issues. *Pastoral Marriage* for 1625 is based on Kussmaul's data for the period 1561-1640; for 1675 and 1725 it is based on Kussmaul's data for 1661-1740; and for 1775 and 1819 it is based on Kussmaul's data for 1741-1820. This variable therefore takes three different values in the five periods. Marriage seasonality is likely to measure the extent of pastoralism in a county with error in any event. This measurement error will be exacerbated by basing the three different *Pastoral Marriage* values on Kussmaul's data for 80-year periods.

A9. The effects of *Pastoral 1290* and *DMV* on female age at first marriage 1600-1837

For the reasons discussed in Section A8, VV's interpretation of the regressor *DMV* in the regressions reported in Table 4 of their paper is flawed. *DMV* does not measure desertion of

[5] The values of *DMV* for the entire period from c. 1086 to after c. 1700 calculated by Broadberry et al. (2015) and used by VV for these four counties are as follows: Oxfordshire 21.7, Warwickshire 20.6, Northamptonshire 12.8, Leicestershire 12.6. For the period c. 1350 to c. 1450 only, the values of *DMV* are Oxfordshire 6.53, Warwickshire 2.41, Northamptonshire 2.19, Leicestershire 1.50. Although the ranking is the same, the relative sizes of *DMV* for the entire period and for the century after the Black Death are very different.
[6] Angrist and Pischke (2009), p. 64.

villages in the aftermath of the Black Death and so cannot be interpreted as a measure of the shift from arable to pastoral production in this period. The regression model we use to analyse the effect of the share of pastoral land in 1290 on FAFM 1600-1837 in the main text therefore omits *DMV* as a regressor. However, for a clear comparison with VV's results, in this section we report results from a regression specification which is identical to theirs. These are shown in Table A2. All regressions in Table A2 include four time-period dummy variables as regressors, the coefficients of which are not reported. For each pair of reported confidence intervals and *p* values in Table A2, the upper one is obtained using Stata's finite-sample adjustment, while the lower one is obtained using the wild cluster bootstrap with Rademacher weights and 9,999 replications (henceforth WCB).

Table A2: IV and OLS estimates of the effect of the share of pastoral land in 1290 and deserted medieval villages on female age at first marriage

	Estimation method			
	IV using ln*(daysgrass)*	IV using crop suitability	IV using ln*(daysgrass)* and crop suitability	OLS
Pastoral 1290	8.085	3.477	5.130	4.036
95% confidence	[3.76, 12.41]	[-2.58, 9.54]	[-0.01, 10.27]	[-0.61, 8.68]
interval	[-∞, 16.09]	[-4.04, 9.70]	[-∞, -13.16] U [-4.01, 11.84]	[-1.47, 9.49]
Elasticity	0.185	0.080	0.118	0.093
DMV	9.266	5.441	6.813	5.905
95% confidence	[2.56, 15.97]	[-1.97, 12.85]	[0.69, 12.94]	[-0.88, 12.69]
interval	[0.73, 16.67]	[-4.42, 12.01]	[-1.89, 11.82]	[-5.18, 11.82]
Elasticity	0.030	0.017	0.022	0.019
Effective *F* statistic	30.07	40.98	14.90	-
p value of exogeneity	0.003	0.610	0.303	-
test	0.246	0.649	0.440	
p value of test of just-identified estimates	-	-	0.160 0.277	-
p value of *J* test	-	-	0.125	-
Adjusted R^2	0.298	0.414	0.408	0.417

Notes: The number of observations for all equations is 112. All equations include four time-period dummy variables as regressors, the coefficients of which are not reported. These estimates were obtained using the Stata command *ivreg2* (Baum, Schaffer, and Stillman 2010). In each pair of confidence intervals and *p*-values, the upper one is based on Stata's finite-sample adjustment and the lower one is based on the wild cluster bootstrap. The elasticities correspond to the point estimate at sample mean values. The effective *F* statistic is that of Montiel Olea and Pflueger (2013).

Source: Authors' estimates.

Equation (A2.1) in Table A2 corresponds to equation (3) in VV's Table 4, with ln*(daysgrass)* used as the single IV for *Pastoral 1290*. The effective *F* statistic suggests that this regression does not suffer from serious weak IV problems. However, although the estimated effect of *Pastoral 1290* is well determined when the 95% confidence interval is based on Stata's finite-sample adjustment for clustered standard errors, it is extremely imprecise when the confidence interval is based on the recommended WCB method. Thus, in contrast to VV, we regard (A2.1) as providing very little information about the effect of pre-Black-Death pastoral agriculture on early modern FAFM. The WCB estimate is so imprecise that the exogeneity test does not reject the null hypothesis that *Pastoral 1290* can be treated as an exogenous variable, in which case OLS estimation is preferable to IV.

In (A2.2) we use crop suitability as the single IV for *Pastoral 1290*. The effective *F* statistic provides no evidence of weak-IV problems in this regression. The point estimate of the effect of *Pastoral 1290* in (A2.2) is smaller than that in (A2.1), corresponding to an elasticity of just 0.08 rather than 0.185. The two confidence intervals corresponding to the different methods of obtaining clustered standard errors in (A2.2) are much more similar than in (A2.1), and provide no clear evidence of a positive effect of *Pastoral 1290* on FAFM. The exogeneity test does not reject the null that *Pastoral 1290* is an exogenous regressor, so again OLS estimation is preferable.

In (A2.3) we use both IVs to obtain over-identified estimates of the effect of *Pastoral 1290* on FAFM. The point estimates in (A2.3) correspond to those of equation (2) in VV Appendix Table B5. The effective *F* statistic suggests that this regression does not suffer from serious weak-IV problems. If the standard errors are obtained using Stata's finite-sample adjustment, the estimated effect of *Pastoral 1290* in (1.3) is almost certainly positive, though not large, with the point estimate corresponding to an elasticity of 0.118. But the WCB confidence interval is extremely wide, so (A2.3) provides very little information about the effect of *Pastoral 1290* on early modern FAFM.

As in the main text, we report both the *p* value of the *J* statistic and *p* values of tests of the difference between the estimates of *Pastoral 1290* in equations (A2.1) and (A2.2) as over-identification tests for equation (A2.3). The two latter tests are based on clustered standard errors from Stata's finite-sample adjustment and from the WCB procedure. None of these tests reject the over-identification restriction at conventional levels. Furthermore, since the exogeneity tests

again do not reject the null, the question of whether one or both of the IVs are invalid does not arise. For equations (A2.1) – (A2.3), the only evidence that IV estimation is necessary is provided by the exogeneity test in equation (A2.1) using standard errors based on Stata's finite-sample adjustment. We regard the WCB standard errors as providing more reliable inference, and the exogeneity test in (A2.1) based on these does not reject the null.

Hence, for the regressions which follow VV by including *DMV* as a regressor, there is no evidence that IV estimation is necessary, so the more efficient OLS estimates in equation (A2.4) should be used. The confidence intervals for the effect of *Pastoral 1290* in (A2.4) based on the two methods of obtaining clustered standard errors are fairly similar, and both include a range of negative values as well as a larger range of positive ones. There is no clear evidence of a positive effect, and the point estimate corresponds to an elasticity of 0.093, which is of very modest economic significance.

Putting to one side the difficult question of how to interpret the estimated effect of *DMV*, is there any evidence from Table A2 that this variable has an effect on early modern FAFM? The only one of equations (A2.1) – (A2.4) in which the WCB confidence interval provides evidence that *DMV* has a positive effect is (A2.1). In this equation, as in the other three, the point estimate of this effect corresponds to such a small elasticity that it is of no economic significance. There is no evidence from these equations that *DMV* influences FAFM 1600-1837. This reinforces our view that *DMV* should be omitted from a regression model which analyses the effect of *Pastoral 1290* on early modern female marriage age.

The conclusion of this section is that, even if *DMV* is included as a regressor, VV's claim that there is evidence that *Pastoral 1290* had a positive effect on FAFM 1600-1837 cannot be sustained. In order to obtain a well-determined positive estimate of the effect of *Pastoral 1290* in this case, it is necessary to make no use of crop suitability as an IV, and to use Stata's finite-sample adjustments to estimate the cluster-robust variance matrix rather than the wild cluster bootstrap. As we have shown, neither of these decisions is justifiable.

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