# Economic-Demographic Interactions in European Long Run Growth


## Abstract

Cliometrics confirms that Malthus' model of the pre-industrial economy, in which increases in productivity raise population but higher population drives down wages, is a good description for much of demographic/economic history. A contributor to the Malthusian equilibrium was the Western European Marriage Pattern, the late age of female first marriage, which promised to retard the fall of living standards by restricting fertility. The demographic transition and the transition from Malthusian economies to modern economic growth attracted many Cliometric models surveyed here. A popular model component is that lower levels of mortality over many centuries increased the returns to, or preference for, human capital investment so that technical progress eventually accelerated. This initially boosted birth rates and population growth accelerated. Fertility decline was earliest and most striking in late eighteenth century France. By the 1830s the fall in French marital fertility is consistent with a response to the rising opportunity cost of children. The rest of Europe did not begin to follow until end of the nineteenth century. Interactions between the economy and migration have been modelled with Cliometric structures closely related to those of natural increase and the economy. Wages were driven up by emigration from Europe and reduced in the economies receiving immigrants.

**Economic-Demographic Interactions in European Long Run Growth**

For most of history until the industrial revolution and the onset of modern economic growth, living standards have been stagnant or periodically falling and rising around a stationary level in response to wars, famines, plagues and climate change. In the absence of technological cor social change population has also tended to a long term balance. Demographic transition is a stylised description of a shift from one type of social order to another. In phase 1 mortality and fertility are high and population broadly stable. Mortality falls in phase 2 but fertility does not, consequently population explodes. In phase 3 fertility drops so that population begins to stabilise at a much higher level (Chesnais 1992). Cliometric analysis (not necessarily under this banner) attempts to link these demographic changes with economic development by explaining fertility and human capital accumulation as the outcome of household decisions that are rational in their environments but that also influence the way their environments evolve. In so doing the aim is to model the transition from a low living standard 'Malthusian' economy to one with continuing rising output per capita, commonly by human capital accumulation.

A country's population is potentially influenced not merely by natural increase – the excess of fertility over mortality – but also by migration. For much of history simply establishing the size of population has been a major challenge for historians, with migration an almost unknown magnitude primarily seen as a source of bias in estimates of birth rates, marriage rates and death rates. But from the nineteenth century, with more effective state control and interest in statistics, usable migration data becomes available. In this field Cliometric analysis has focussed primarily on the vast movements across the Atlantic before the First World War. Because a survey has been recently published (Hatton 2010), the concern here is with the commonalities of modelling population movement and population change through natural increase.

These themes matter because the size and quality of an economy's population has been critical for its military and economic success and even its survival. Population is a tax base and source of military recruitment. Some economies at particular times have considered themselves over populated and encouraged emigration. Others have believed they were under-populated and promoted immigration or family-friendly policies. Most populations change primarily, not from migration but from ‘natural increase’, the excess of births over deaths, Natural increase of different group has been and can be a source of social tension, as has immigration; one response has been legal restrictions on immigration, pressure for which has not disappeared.

The 1601 Poor Law in England was unusual in the early acknowledgement of some state responsibility for sections of the population in difficulty. Elsewhere their relief was left to charity or religious organisations. A question that exercised English social thinkers in the late eighteenth century still concerns some today; if the state gives financial support for families with low earnings, will this encourage indigence and a larger population? A related policy concern has been, will encouraging or permitting immigration lower domestic wages and employment, and encouraging emigration raise domestic wages and job opportunities?

In the following survey, section 1 discusses the sources and data used by the Cliometric literature, section 2 presents the literature on natural increase of population in a simple Malthusian model framework, section 3 considers the possible ways that a shift could be made to modern economic growth, section 4 extends the Malthusian framework to selected Cliometric migration literature, section 5 considers approaches adopted to identification and section 6 outlines the distinctive approaches of some recent studies that use time series methods.

***Data***

How far Cliometrics can proceed plausibly depends upon the nature of the available evidence. The more distant past is generally more problematic in this respect than the more recent. Much effort over many years has been devoted to establishing the historical course of demographic and economic variables, with some surprising results. The Emperor Diocletian’s Price Edict of AD 301 has allowed a comparison of Roman living standards with those of the medieval and modern worlds (Allen 2007). The culmination of work by Thorold Rogers (1866), Beveridge (1939), Phelps-Brown and Hopkins (1955, 1956, 1981) in Clark’s (2005) annual English real wage (for builders, coal miners and agricultural workers) series beginning in 1200 is no less remarkable. English real wages were apparently higher in 1200 than in 1800 and in 1450 they were higher than at both these dates.

Swedish data on real wages show even more extreme contrasts, suggesting that unskilled labourers were better off in the late Middle Ages than in the mid-19th century. After about 1540 the trend in real wages in Stockholm is downward so that by 1600, real wages were some 40 per cent lower than in 1540 (Soderberg 2010). This remarkably strong fall occurs elsewhere in Europe as well (Allen 2001). The difference between Britain and the Netherlands on the one hand and southern Europe on the other is that the first two countries recovered the 1450 peak by the mid-nineteenth century but the south did not. Like the Swedish series the German real wage series beginning in 1500 are derived from builders wages (Pfister et al 2012). But experience in Germany differed because of the labour scarcity created by the devastating demographic consequences of the Thirty Years War. Over the first half of the seventeenth century, the war period, the German real wage rose by 40 percent. By the end of the third quarter century wages had climbed to the level at the beginning of the sixteenth century.

The foregoing wage series all refer to men's earnings. Humphries and Weisdorf (2014) have constructed indices of women's casual and contractual wages in England between 1260 and 1850 which show a different pattern from men's wages. Women's annual wages were held down by regulation more than males in the labour scarcity period of the 14th and 15th centuries, reducing the incentive to postpone marriage and reduce fertility. Married women gained from more buoyant casual wages and by accessing the better paid male labour market through their husbands. When industrialisation arrived the position of the two types of female employment was reversed. Women who could not commit to annual contracts fared less well, increasing the reliance of married women on the male earner.

Human capital indicator series, that might eventually reflect the level of skill, are much more fragmentary, but no less intriguing. Literacy, book production, subscribers to the Encyclopédie, and age heaping have all been enlisted as indicators (A'Hearn et al 2009; Baten and van Zanden 2008, Squicciarini and Voigtländer 2014). Most are distinguished by their tendency to rise strongly in early modern Europe– before the onset of sustained increases in national income. This may be why Allen (2003) finds no effect of literacy on economic development measured by wages, though perhaps the impact is concealed by the close link with urbanisation which he does find important. In France illiteracy rates fall sharply from 65 percent to 5 percent between 1720 and 1880 (Diebolt and Perrin 2013).

Tax surveys or returns, private or national censuses, and listings for military, civic or religious purposes have all provided the raw material for constructing estimates of population, fertility and mortality[1]. Perhaps the best known early European census of population and assets is that of 1086 in England, in the Doomsday Book. By the end of the eighteenth century, governments were beginning to undertake censuses regularly. The first official US population census was in 1790 and the first British official census was in 1801. But for the sixteenth to the nineteenth centuries, parish registers of baptisms, marriages and deaths have provided the principal sources of key demographic variables through aggregation and family reconstitutions in Europe.

Family reconstitution entails tracing individuals from birth, through marriage and births of children to death. Adding up these individual reconstitutions across a parish potentially provides measures of life expectation, age at marriage, fertility and other indicators. Drawbacks include the difficulty of linking names in the different registers, migration reducing the continuity of experience and the possibility that substantial portions of the local population were not included in the registrations, either because of shortcomings of the recorder or because some people were able to choose not to register, perhaps for religious reasons. Migration from parishes of birth can bias estimates of mean marriage age and life expectancy even when demographic characteristics of migrants and non-migrants are similar (Ruggles, 1992). Only those married in their place of birth are included in the family reconstitution. Late marriage is more likely to take place after migration and so to be systematically excluded from the data. Early deaths are over-represented in reconstitutions because those who live longer and have time to migrate will die elsewhere—and be omitted.

Good quality parish registers have a high survival rate in France, Spain and Italy. Sweden (and Finland) supplement registers with listings of inhabitants by house with notes on religion, reading ability and migration in the seventeenth century (Flinn 1981). For England Wrigley and Schofield (1981) established mortality and fertility rates by family reconstitution of 404 Anglican parish registers of baptism, marriage and burial, for which the earliest date from the beginning of registration in 1541[2]. Wrigley and Schofield also used the data from parish registers to calculate population by 'Back Projection'[3]. This involved back dating and revising the age structure of the

[1] When interpreting these materials it is important to appreciate that aggregated data can conceal relations that are apparent in more disaggregated sources of information (Brown and Guinnane 2007). The Princeton Fertility project in particular (for instance Coale and Watkins 1986) has been criticised for drawing incorrect inferences from excessively aggregated data.

[2] The Cambridge team also published a much more detailed analysis based upon 26 English parishes (Wrigley et al 1997).

[3] Lee and Anderson (2002) contend that the resulting population estimates are inaccurate as a method of taking into account international migration, but a fair representation of population excluding migration.

1871 population census at five year intervals by taking into account flows of previously occurring 'events'. Age at death was not stated in the register before 1813 so deaths were allocated to age groups by a model mortality schedule.

The high famine and plague-induced mortality of the 14th and 15th centuries is a critical demographic event for western Europe[4]. The Great European Famine of 1315-17 and subsequently in England, diseases of cattle and sheep and drought (Dodds 2004; Stone 2014), followed by the Black Death of 1348, drastically reduced populations. Moreover the plague returned in 1361 and 1369, as well as later, with diminished force. In Sweden population fell from 1.1 million to less than one third between 1300 and 1413. Not until the mid seventeenth century did the population recover, and sustained growth only resumed in the later part of the century (historical statistics.org). In England it is clear that there was a massive decline in population, perhaps until the middle of the fifteenth century. In the Durham area, tenant numbers imply that population fell to 45 percent of pre-Black Death levels by the end of the fourteenth century, and tithe evidence indicates a similar collapse of output (Dodds, 2004). Clark's (2007) calculations from wage data reach a broadly comparable conclusion for aggregate English population. Tuscan population decline was apparently even more severe; between 1244 and 1404 the population of the Pistoian countryside fell to less than one third of its former level and the city population fell to one half (Herlihy 1965). In Germany the Thirty Years War of the early seventeenth century was a comparable mortality crisis, with population falling by more than one half (Pfister and Fertig 2010).

***Population, Natural Increase, and the Economy***

The literature survey is initially structured around Malthus's (1970) fundamental treatment, presented as a two equation model. This allows a wide range of Cliometric and related literature to be interpreted. Such was the importance of Malthus's theorising about the relation of the economy and population that he earned the rare accolade of posthumous transformation into an adjective. His work is therefore the natural beginning for a historical survey of the interaction of demography and economy.

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[4] For an interpretation on film of the impact, see Ingmar Bergman's *The Seventh Seal*.

Malthus behaved like a true social scientist, combining empirical evidence and theory. Among other data sources he utilised Alexander von Humboldt's observations of Spanish-American population behaviour and, indirectly, the United States census, to contrast with European demographics. Malthus's focus on the geometrical progression of population increase compared with the arithmetic progression (at best) of food increase, when there was little extra land that could be brought into cultivation, proved compelling. Whereas in the Americas population doubled every twenty five years because land was abundant, in the hilly or mountainous parts of Europe, like Switzerland or Wales, there was virtually no increase, because of 'positive' or 'preventive' checks.

Positive checks shorten the natural duration of life; they include poverty, famine, pestilence, great cities (with their high mortality induced by work, living and leisure styles) and war. Bubonic plague was the biggest killer in western Europe from the fourteenth to the seventeenth century. Thereafter quarantine regulations kept it at bay. Typhus and smallpox then assumed pre-eminence (Flinn 1981 ch 4). Urbanisation must also have contributed to holding up mortality as the severity and frequency of bubonic plague declined. In 1500 London was estimated to contain 40,000 people and Paris 100,000, but the populations of both cities exceeded half a million by 1700 (de Vries 1984). Another type of mortality check originated from the failure of two or more harvests in a row, as in Finland by 1697 or Ireland by 1846. Poor transport infrastructure and the high cost of moving food meant that these crises were likely to be localised, although the Great European famine of 1315-17 was an exception. Movement of armies could generate mortality crises even in the absence of fighting. The Thirty Years War in Germany was as lethal to the civilian population as the Black Death, because of disease spread, and crop and livestock destruction and confiscation, by marauding troops.

Preventive checks act on the effective birth rate; for Malthus these included delayed age at marriage, 'unnatural passions' and abortion. Some combination of these checks constrains population to the fixed land resources of long settled regions. Subsequent research (Hajnal 1965) showed that substantially delayed age at first marriage of females until around an average age of 25 was indeed the norm in western Europe at the time Malthus was writing and for some centuries before (de Moor and van Zanden 2010). Moreover, this custom was unique to western Europe. Everywhere else the average marriage age was lower. The customary justification for 'restraint' in western Europe was the need to accumulate or acquire sufficient resources to create a separate household for a married couple. The other form of preventive check, or 'moral restraint', in Europe that was unusual by world standards was that perhaps 10 percent or more of females never married at all. In conjunction with social sanction that held illegitimacy to low levels – perhaps 2-5 percent – these 'moral restraints' limited population growth and the level of population below the rates that otherwise would have prevailed. Using English data Crafts and Ireland (1976) suggest that in the late eighteenth century a rise of three years in the age at marriage could have at least halved the population growth rate.

A policy implication, Malthus maintained, was that raising Poor Law payments with the number of children in the family would incentivise a larger population and undermine independence. The attractions of the ale house, and of large families, he contended, would be diminished if the labourer knew there were no state handouts to fall back on. Cross-section regression of English parishes by Boyer (1989) indeed indicated not only that higher wages were associated with more births (an elasticity of 0.4) but child allowances stimulated more births; parishes that paid allowances with the third child had 25 percent more births than those that paid no allowances. Boyer tests Huzel's (1980) suggestion that the allowance system was more likely a response to population increase and finds, on the contrary, that the allowance system was exogenous to births.

On the other hand Kelly and O'Grada (2014) find that the disappearance of the positive check coincided with the introduction of systematic poor relief. They are able to cite Malthus himself as an authority for the likelihood that government action contributed to breaking the link between harvest failure and mass mortality. On the European continent, where there was no Poor Law, men and women could not count on relief from hardship, unlike in England, and this had profound consequences for economic development (Solar 1995). They were unwilling to break their ties with the land and become the labour force of an industrial revolution.

Not only did Malthus identify long run equilibria, or steady states of population and wages, but he also noted the likelihood of a population and wage cycle. 'Over-population' drives down money wages and pushes up food prices. This reduction of real wages discourages marriage and so population stagnates or declines. But low wages encourage the extension of cultivation and improvement of land already cultivated until real wages recover with the stronger demand for labour, and population expansion resumes.

'This sort of oscillation ….may be difficult even for the most penetrating minds to calculate its periods.' Malthus 1970 p77.

We can simulate these oscillations, in response to a mortality shock for instance, to show a key feature of the Malthusian model. This exercise in 'deterministic calibration' illustrates an approach that has proved popular in demographic- economic interaction modelling in recent years (albeit with more complex models). In a stylised discrete time model of the Malthusian process the relevant single period may be at least 15 years, but perhaps double that. The wage in the current period ( $w_t$ ) falls with the population in the current period ($P_t$ ), (which brings the labour force on to the market), due to the diminishing marginal product of labour, and the fixed available land[5]. Where $u_t$ is a random disturbance term with mean zero, and a and b are parameters:

$$w_t = a - b.P_t + u_t \quad \ldots a, b > 0 \ldots.(1)$$

Pfister et al. (2012) for Germany from 1500 find a strong negative relationship between population and the real wage until the middle of the seventeenth century that probably reflects this relationship. A plausible estimate of b is 0.5 according to Lee and Anderson (2002). (This assumes an elasticity of substitution of about 1 and labour's share in national income of 0.5. [6]) Allen (2003) measures the effects of population in this type of equation by the land to labour ratio in a cross-European country panel beginning in 1300 and ending in 1800. He estimates an elasticity of 0.4, when the *a* parameter in (1) above is a function of urbanisation and total factor productivity in agriculture. Crafts and Mills (2009), using time

[5] In practice cultivated land area expanded a little with population in western Europe, as less productive soils were brought into use. Broadberry et al (2011) estimate that in England the cultivated land area only exceeded the medieval peak of 1290 by 1836, when population was several times greater than at the earlier date.

[6] Defining W as log w and p as log P (=the labour force), the marginal productivity condition is W=a-0.5(p - q) where q is the log of output and the elasticity of substitution between factor inputs is unity. An additional assumption is that there should be close to perfect competition in labour markets.

series English data from 1540, estimate a much higher elasticity of 0.95 for *b* (compared to Lee and Anderson's (2002) b=1*).* One source of the difference from Allen may be that the time series approach captures short term relationships which are less responsive than the long term coefficients obtained from the panel data. Another possible reason is that Allen includes a wider range of explanatory variables in his model, leaving less wage variation to be explained by population. Crafts and Mills also find the shift in *a* up to 1800 is an average rate of technological progress of 0.75% per annum using Wrigley and Schofield's real wage series and 0.4% when Clark's more broadly based series is employed. Cervelatti and Sunde (2005) extend equation 1 by distinguishing two wages, arising from the demand for skilled labour and the demand for unskilled labour, an approach also followed by Diebolt and Perrin (2013).

A second, quite different, relation connects population and wages. Population in the current period $P_t$ increases with the previous period wage because higher wages encourage earlier marriage and because children are 'normal goods' (the diminution of the preventive check): as household income rises more children become possible[7]. As well as the effect on births, at low living standards higher wages reduce positive checks to premature death.

Population reflects the balance between births and deaths, along with migration. Ignoring migration, that is focussing on 'natural increase', population measured at the end of period t is equal to population at the end of period t-1, plus the excess of birth (B) over deaths (D) over the period t;

$$P_t = P_{t-1} - D_t + B_t .$$

For the moment we will not distinguish theoretically between positive and preventive checks, simply recognising that both, and their net effect, may depend upon the level of

[7] In reality there may be longer lags in this relationship, which in turn lengthens the periodicity of the cycle discussed below. Autocorrelated shocks or disturbances have the same effect.

wages[8]. Where $v_t$ is a random disturbance term with mean of zero, and c and d are parameters;

$$P_t = c + d.w_{t-1} + v_t \quad \ldots c, d > 0 \ldots .(2)$$

Allen (2003) estimates a long run equation of this form for early modern Europe and finds a positive coefficient *d* for the Netherlands and England and Wales but no long run response for the other European countries in his sample. Evidence from a version of (2), distinguishing the effect of wages on birth rate from that on death rate, includes a median of 14 European countries fertility response to wages from 1540-1870, estimated at an elasticity of 0.14 and for England, of 0.12 (Lee and Anderson 2002 Table 2). Mortality elasticities for England go down to -0.076 with an indication of higher rates – perhaps -0.16 - elsewhere in Europe. These numbers imply stronger positive population responses to wages in Europe as well as in England. In the long run the coefficient *d* may tend to infinity, so that wages eventually return to some customary subsistence level after an increase in productivity. This is consistent with Ashraf and Galor's (2011) findings[9].

An alternative measure of (the inverse of) wages, which has the merit of exogeneity to population and birth and death rates, is food prices. After 1740 there was no response of death rates to food prices in France, perhaps a century later than in England (Weir 1984). French marriages were more responsive to price shocks than the English, but in the nineteenth century there was a weakening of this French preventive check. In eighteenth century Sweden a 15 percent rise in rye prices was associated with at least a 3 percent increase in mortality the following year (Bengtsson 1993). Sweden also showed evidence of the preventative check in both centuries, with higher rye prices reducing marriage rates and fertility.

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[8] When birth and/or death rates respond to wages, as for example in Lee (1973), then equation 2 explains the change in population and should be modified by the addition of - $P_{t-1}$ to the right hand side. In the interests of simplicity this modification is not implemented here.

[9] And with Arthur Lewis' (1954) model of economic development with unlimited supplies of labour, although here the perfectly elastic supply of labour comes from migration, rather than natural increase.

Lagerlof (2003) postulates that $v_t$ (in equation 2 above) is primarily due to mortality shocks, the values of which play a critical role in the break out from the Malthusian equilibrium. He also derives an analogy to equation 2 from household optimisation of a preference function for surviving children, human capital, and goods. This theme is developed by Foreman-Peck (2011) who shows that a fall in child mortality theoretically reduces target births but increases desired family size and population. Across late nineteenth century Europe and across English counties lower mortality rates are actually associated with lower birth rates.

From equations (1) and (2) (substituting out wages) and assuming the disturbance terms take their mean values, we obtain a first order difference equation for P:

$$P_t + bd.P_{t-1} = c + ad \qquad ...(3)$$

Given the initial condition, the population in the base year $P_0$, we can solve the difference equation:

$$P_t = \frac{c+ad}{1+bd} + \left( P_0 - \frac{c+ad}{1+bd} \right) (-bd)^t .$$

The first right hand side component is the particular solution. In the limit this is the steady state value of population. The second right hand side term is the complementary function with a characteristic root equal to $-bd < 0$. Population will oscillate around the steady state (particular solution) every period until it converges to the equilibrium level (as long as $|bd|<1$).

The wage equation corresponding to the population equation (3) is:

$$w_t + bd\, w_{t-1} = a - bc \quad ....(4)$$

The solution to this wage difference equation is:

$$w_t = \frac{a-bc}{1+bd} + \left( w_0 - \frac{a-bc}{1+bd} \right) (-bd)^t$$

Higher living standards are achieved by larger values of *a* and lower values of *c, b* or *d*. A higher marriage age lowers the population by reducing *c* and *d*. Exogenous population growth, measured by the growth of *c*, drags down wages. This could be due to falling mortality, as Boucekkine et al (2003) postulate when they calibrate their model with mortality schedules from Venice 1600-1700 and Geneva 1625-1825. Quarantine regulations in this period were supposedly increasingly successful in diminishing outbreaks of plague in Europe (Chesnais 1992 p141). Conversely if urbanisation was sufficiently important to raise national mortality rates (Voth and Voigtlander 2012), *c* would fall and wages would rise. Wrigley and Schofield (1989 p475) maintained that, in the half century after 1820, the rapid increase in the proportion of the population urbanised contributed substantially to the failure of English life expectations to rise significantly (though this is after the Voth and Voigtlander period).

Deterministic calibration typically chooses values for parameters *a*-*d* so that the model tracks the historical series of interest. More ambitiously the researcher may adopt parameter values that have been estimated. Based on the calibration $a = 1$, $b = 0.8$, $c = 1$ and $d = 0.8$ the steady state for wages to which the system converges is $w^* = 0.12$ and for population $P^* = 1.097$, The dynamics of the Malthusian process can be shown with an Excel spreadsheet[10] and by rearranging the system as follows;

$$P_t + 0.64.P_{t-1} = 1.8$$

$$w_t + 0.64\, w_{t-1} = 0.2$$

Starting with values of 1, Figure 1 shows the inverse fluctuations in population and wages in response to very large initial shocks, cutting population and boosting wages. The figure

[10] Enter the parameters of the population difference equation in say cells A1 and A2 ( respectively 0.64 and 1.8 in this case). Fill a column ( say B) with a series starting at zero and increasing by one with each subsequent cell.. Assign the column next to B for Pt. The first value depends upon the shock to be considered. A positive shock us any number greater than 1.097 here. So entering 1 as the first cell in the C column will be a negative population shock. In cell C2 enter '=-$A$1*c1+$A$2' and fill down column C. The series rises above the equilibrium level in period 1 and falls below it in period 2. The behaviour of the equation can be studied by changing the parameters assigned to cells A1 and A2.

shows convergence on $w^* = 0.12$ and $P^* = 1.097$, getting quite close over 10 periods, perhaps 150 or 300 years (in the absence of other shocks, if each period is 15 or 30 years). The initial levels can be considered to represent a positive mortality shock, such as those of the 14th and 15th centuries in England or the Thirty Years War in Germany, cutting the population and boosting wages.

< FIGURE 1 ABOUT HERE>

In summary, two features of this simple dynamic model are the very long lasting oscillation and the inverse movements of wage and population. It is a homeostatic system returning to an equilibrium of population and wages. Are the theoretical cycles realistic? Lee (1993) maintains that at the macro-economic level homeostasis has only been a weak background force. The approximately 250 year European cycle was mainly driven by exogenous and probably autocorrelated shocks. On the other hand, there is much evidence that for most of history there has been a stable Malthusian equilibrium of wages and population (Ashraf and Galor 2011). Across countries, land productivity and the technological level affected population density in the first to the sixteenth centuries, whereas the effects of land productivity and technology on income per capita in these years were not significantly different from zero.

***Demographic Transition and Economic Growth***

A break out from the above Malthusian equilibrium can be achieved in two general ways. The first is by incomes becoming sufficiently high that the time opportunity cost of children ensures that the negative substitution effect dominates the positive income effect. Then the *d* wage coefficient falls in the population equation (2), perhaps even becoming negative. This could be one interpretation of the high mortality 14th and 15th centuries in western Europe that pushed wages to unprecedented heights. With high wages there is a high value of time, and so a desire to limit numbers of children – through the Western European Marriage Pattern, which appears to have arisen around this time. A variant explanation for fertility change is that the mortality shock and higher male wages switched demand towards meat, thereby encouraging the expansion of pasture at the expense of arable farming. Pasture was supposedly more conducive to higher women's wages which encouraged later age at marriage and lower fertility (Voigtlander and Voth 2013). However, women's wages in England do not seem to have conformed to this pattern (Humphries and Weisdorf 2014).

Demographic transition in Europe as conventionally understood refers not to this earlier period but to the nineteenth century when population growth generally increased strongly, and real wages did not fall any further. This last suggests the second break out possibility at work; an acceleration in the pace of technical change, represented in equation 1 by an increase in the *a* coefficient (and perhaps a fall in *b*). Malthus predicted that faster technical progress would be absorbed by greater populations, as birth rates rose. But real wages do not fall in this scenario. By contrast, a permanent mortality shock, reducing death rates, would instead lower wages as population increased, until positive or preventive checks intervened. The next phase of the demographic transition involves such checks, especially a fall in the *d* coefficient.

The early French fertility transition described by Weir (1984) after 1830 is consistent with rising living standards reducing the demand for children; a slightly rising age at marriage was accompanied by falling marital fertility. Unlike France, only after 1900 did sustained fertility decline began in much of Bavaria, when the signs of rising opportunity costs of children become apparent. By 1910 urbanization strongly reduced rural marital fertility (Brown and Guinnane 2002). Textile employment, a measure of non-agricultural opportunities for women, markedly cut fertility, as did higher women's wages. Conversely, women on small farms that relied primarily on family labour were more likely to have more children. A time series analysis of the British fertility decline found that illegitimacy lagged accounted for almost one third of the decline, where illegitimacy is assumes to be an indirect measure of contraceptive costs (Crafts 1984). Crafts (1984) maintained that the cheaper or more widely understood was contraception the lower would be both illegitimacy and the legitimate fertility.

The second break out possibility (changing the sign of *b*, the population coefficient in the wage equation) is in effect postulated to have occurred by population size boosting technological advance in Unified Growth Theory (Galor and Weil 2000). The interpretation could be extended to include market widening, such as the European discovery of the Americas - Smithian growth (cf Acemoglu et al 2005).

Alternatively if *a*, the intercept in the wage equation, is increasing due to technological progress - perhaps from human capital accumulation – the negative effects of population on wages operating through b might be offset. An early discussion of the difference between US and British technology stemming from land-labour ratios might be invoked to explain different rates of technical progress after a demographic shock. Labour scarcity in the US – and/or perhaps land abundance – supposedly encouraged the adoption of more capital intensive techniques and stronger technical progress ((Habakkuk 1967; David 1975 ch. 1). These ideas might be transposed to other economies experiencing shocks that radically altered factor ratios. Then greater technical progress might be triggered by shocks increasing labour scarcity (such as the Thirty Year War in Germany or the high mortality fourteenth century in western Europe).

Lee and Anderson (2002) define the population absorption rate of an economy as the rate at which population can grow without a fall in real wages. This depends upon the growth in *a* relative to the growth in *c* (in *equation* 2). This balance was likely to change, and at different times in different countries. French exceptionalism appears with widespread evidence of marital fertility control in France in the 1790s (reducing *c*), nearly 100 years before comparable evidence in England (Weir 1994). In Germany, the negative relation between wage and population size (equation 1) was weaker in the eighteenth than in the sixteenth century; the fall of the marginal product of labour was less pronounced, and the beginning of the eighteenth century saw a marked increase in labour demand (Pfister et al 2012). German labour productivity experienced a strong positive shock during the late 1810s and early 1820s, and continued to rise at a weaker pace during the following decades. Sustained economic growth began well before the beginnings of German industrialization, in the third quarter of the nineteenth century.

Natural selection in favour of higher child quality (Galor and Moav 2002) cumulatively has this consequence of raising technical progress or, increasing *a*, as may falling mortality. Higher life expectancy can raise the returns to investment in human capital because there is a longer period over which the benefits accrue. Eventually accumulation can trigger an acceleration of technical progress (Boucekkine et al, 2003; Lagerlof 2003; Cervellati and Sunde 2005). Or higher child survival chances simply might increase parental preferences for child quality (Foreman-Peck 2011). In this last case higher female marriage age is hypothesised to increase the rate of human capital accumulation through 'child quality' family choice as well. Assuming literacy is a measure of child quality and human capital, the hypothesis is supported by the finding that the proportion of single females aged between 25 and29 negatively predicts illiteracy across Europe, controlling for schooling. Moreover, illiteracy in English counties in 1885 is negatively associated with age at marriage. Controlling for prior school attendance and literacy appears to contribute to output in a cross-Europe production function for the years 1870 to1910.

With less emphasis on family consensus, Diebolt and Perrin (2013a,b) identify gender empowerment increase as the key for the shift towards child quality. Empowerment increased the amount of time invested by women in their education and fertility therefore declined. These choices shifted outcomes from quantity of children towards quality of children. Female literacy was associated with falling fertility in France in the period 1881-1911, which Diebolt and Perrin describe as evidence for a child quality-quantity trade-off.

Inspection of equation (3) suggests that if *a* increases continuously, then population will eventually 'take off'. The same applies to the wage difference equation. Fig 2 shows the effect of a linear time trend superimposed upon the Malthusian population cycle. Initially there is no noticeable effect; the cyclical response to the initial shock is similar. But the peak in period three is a little higher than in the model with the static equilibrium. After period six, population is growing continuously, though obviously the strength of the time trend determines when the break out occurs.

<FIGURE 2 ABOUT HERE>

The end of this phase of the demographic transition comes as incomes rise, and preferences change towards less time-intensive activities than child rearing (that also become more abundant), bringing down birth rates. Technological change favouring brain over brawn altered the gender division of labour so as to favour fewer children as well[11]. In terms of the simple model technological progress, reflected in continuous increases in *a,* must raise real wages continuously. Since real wages are growing, the opportunity cost of children will be rising. This implies that d, the response of population to wages, may be falling. When *d*=0, population stops growing. However, wages continue to grow at the rate given by the growth of a. A ‘demographic transition’ then is completed by two changes; the rise in a and the fall in *d*.

***Migration and the Economy***

The Malthusian scheme also provides a conceptual framework to assess the impact of labour force/ population growth induced by European migration. In the growing International economy of the nineteenth century millions sailed from Europe to new lives across the Atlantic. These bursts of migration triggered lagged increases in building activity to absorb them, and more rapid (extensive) economic growth than could be supported by natural increase alone. Much of the cliometric literature has been concerned with the forces of ‘push’ from the country of origin, or ‘pull’ by the destination, behind migration (Thomas 1973: Hatton and Williamson 1998: O’Rourke and Williamson 1999: Hatton and Williamson 2006, Hatton 2010).

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[11] Alesina et al 2011 maintain that plough based agriculture led to lower female participation in wider society and the economy, and conversely. Presumably ploughing required greater physical strength than shepherding..

A technology shock (perhaps railway building) in the region of recent European settlement increases the demand for labour (*a* rises), and raises wages there.

$$w_t = a - b.P_t + u_t \quad ...(1)$$

Higher wages eventually means ( a 'pull' for) higher immigration and therefore higher population in the recipient region:

$$P_t = c + d.w_{t-1} + v_t \quad .....(2)$$

This is exactly the same model as used to represent the Malthusian economy, but by the later nineteenth century the Atlantic economy was expanding fast, with a continuously rising *a* parameter. There is a positive correlation of the real wage and the upswing. In the region without the positive shock, less labour and capital are supplied, because better returns are to be had elsewhere. In the booming region, the time necessary for building the infrastructure to take full advantage of the technology means that the flow of labour and capital continues for some years, until marginal returns are equalized again between regions (allowing for non-pecuniary differences and costs of migration), or other shocks occur.

An early Cliometric calibrated cyclical model of this process for an export economy was presented by Parry Lewis (1960). The region of immigration exports 'coal' (Parry Lewis had in mind later nineteenth century Wales but probably today the term would be replaced by 'tradable goods'). Also the economy has a 'building' sector ('non-tradeable (capital) goods'). When conditions abroad cause the demand for exports to oscillate or grow in a particular pattern, then the cycles and growth would be reflected in building. If, in addition, exogenous population pressure abroad ('push') causes waves of emigration, then the building sector will fluctuate similarly. This endogenous cycle is heavily damped but endogenous immigration reduces the degree of damping.

Demographic impulses ('push' from the origin countries) as well as technology shocks promote the distinctive inverse cycles between the regions[12]. A case in point is the Napoleonic war "baby boomers" (a rise in *c*) that, in due course Thomas (1973) maintains, created the "hungry forties." Malthusian pressure in Europe pushed migrants to the U.S., capital tended to follow them and the demand for housing in the U.S. rose (even though, in contrast to the positive technology shock, real wages in the receiving region fall, relative to what they would have been).

To the extent that the immigrants are complementary to the indigenous work force, wages will rise. More likely, as assumed above, is that some wages (say skilled) will rise and others fall – if, for instance, immigrants are unskilled. The more capital that flowed with the migrants the stronger the economic growth they promoted, and the less adverse the impact on wages. Taylor and Williamson (1997) calculated that in the absence of mass migration after 1870 real wages in 1910 would have been higher by 27% in Argentina, by 17% in Australia and by 9% in the USA. The pervasive nineteenth century innovation of railways was a major shift in technology for which immigration amplified the impact on output, while reducing output per head in Malthusian fashion (Foreman-Peck 1991 pp87-88). The more responsive immigration was to wages, the lower was steady state output per head.

In the sending region migration was a partial alternative to mortality as a positive check, for instance in Ireland and Germany in the 1840s. In a Malthusian economy, emigration simply made space for a higher natural increase. In a neoclassical growth model economy on the other hand, with exogenous population growth and an unchanged savings ratio ($d$=0 in the Malthusian scheme), output per head and wages would be raised by emigration. Emigration explained about half of the rise in wages across Swedish counties between in 1870 and 1910 (Ljungberg 1997). Taylor and Williamson (1997) estimate that in the absence of emigration,

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[12] Both types of shocks may be classified as originating on the supply side and as 'real' rather than 'monetary', consistent with Real Business Cycle theory (Kydland and Prescott 1982)

real wages would have been lower by 24% in Ireland, by 22% in Italy, but by only 5% in Great Britain, and 2% in Germany.

Immigration restrictions in the two equation model discussed have a similar effect to Malthus's prediction of a reduction in child benefit under the 1601 Poor Law. They reduce the population response to higher wages (reduce the value of *d* in equation 2). From the end of the US Civil War to the 1920s, European immigration provided strong competition to internal US migration from the southern states to the urban North and West. So US immigration restrictions of the 1920s favoured black migrants from the South who gained from the elimination of European competition (Thomas 1973: Williamson 2005)[13].

In Europe, the countries of emigration, the effects of the closure of the US were less benign. Agricultural protectionism in Europe was encouraged by redundant populations, unable to move to the US, who were instead employed growing subsidised crops (Thomas 1973). Migrants were also diverted to Canada and South America, boosting output there.

***Identification and Estimation***

Much of the Cliometric literature is inevitably concerned with how we know or can estimate the values of the parameters of the favoured model. If we find an association in time series data between wages and population, in principle it could reflect relations generated by one or both of the equations in the model we have been discussing. We cannot infer any of the parameters *a, b, c* and *d* from the estimated relation without further information; the original equations are not identified.

If we can distinguish shocks to, or variables affecting, one equation that do not affect the other, then we have a chance of identifying the parameters. A mortality shock because of

[13] Williamson (2005) also discusses the corollary that the position of blacks deteriorated after 1970 because of competition from immigrants.

plague might affect the demographic response to wages (equation 2) but not the equation 1, derived from the production function. In this case the response of wages to the exogenous shift in population traces out the effect of the *b* coefficient of equation 1.

Clark (2007) and Schiedel (2010) use this principle to construct or infer population numbers. Scheidel observes that the second century Antonine and sixth century Justinian plagues of the Roman Empire were associated with higher Egyptian real wages, from which he infers that population must have fallen substantially on these occasions. Clark (2007) reconstructs English population back to 1200 with a peak of 6 million around 1300 on the basis of equation 1. An example is the rise in agricultural wages attributed to population scarcity created by the mortality crises of the fourteenth century.

Harvest failures might lower real wages in a pre-industrial society for reasons outside the model; they are $u_t$ in equation 1, an exogenous shock. If so they could be used to identify the demographic response (equation 2). Higher food prices lower the value of the real wage exogenously, and the effect on population change might be assessed, perhaps especially through changes in marriage rates. In this case the lagged responses are a major potential problem because by the time population responds other shocks with which the harvest failure may be confused will have struck the economy.

Subject to this qualification, if wages fall and population rises, the dominant shock must be demographic (equation 2). If wages rise and population rises the dominant shock is technological, such as harvest failure. But this classification only distinguishes the dominant shock, not how much of the change in population and in wages is due to which type of shock.

An illustration of the identification problem arises in the interpretation of early modern European wage movements with the two equation model. Real wages in the cities of north-west Europe tended to increase, or at least did not fall, by 1850 compared with 1450. But in southern and eastern Europe they did decline, with few exceptions. Allen's (2001) interpretation, shown in figure 3, is that this was due to more vigorous economic development in north-west Europe – in Britain and the Netherlands in particular. In principle the divergence could have been due to a stronger exogenous growth of population in southern Europe (a greater rightward shift of 'labour supply' in the figure) with similar rates of economic development expanding the demand for labour. Apart from the qualitative evidence to the contrary, the stronger growth of population in Netherlands and Britain than in Spain or Italy identifies the greater shift as in the demand for labour. But we cannot conclude that there was no technical progress in southern Europe, only that there was less than in the north-west.

With the more recent demographic-economic interactions, more variables are available for identification. For migration modelling it is important to note that population is a stock and migration is a flow that adds to the stock in the same way as do births. Migration may be due to changes in wages (equation 2), and /or it may cause wage changes (equation 1). If we can find variables that cause migration but do not cause wage changes then we are more likely to identify the migration equation correctly. The migrant stock in a destination has been used to identify migrant flows to the country, along with employment rates in the origin economy ('push') (for example Hatton and Williamson, 2005, p. 65).

***Time Series Analyses***

We have discussed calibration of structural equation models. The econometric alternative for estimating identified economic-demographic models is generally concerned with time series analysis. The study of preventive and positive shocks in particular has utilised Vector Auto-Regressions (VAR) and impulse response functions. VAR analysis arose from the difficulties of identification, of finding any truly exogenous variables. Past values of every variable in the model are assumed to be potential influences on current values of these variables. In the two equation model the following equations would be estimated, although with more lags than written:

$w_t = a + bP_{t-1} + c\, w_{t-1} + u_t$

$P_t = g + d\, w_{t-1} + f\, P_{t-1} + v_t$

This system of equations can be thought of as encompassing a number of structural models in an unrestricted way; for example the original equations only allowed past wages to influence population, whereas now past population does as well.

The residuals, $u_t$ and $v_t$ represent the unexplained movements in population and wages, reflecting the influence of exogenous shocks (ie shocks that arise outside the assumed model). These residuals are now an aggregation of the various exogenous shocks affecting the endogenous variables in the underlying structural model. Therefore, no economic interpretation can be derived from the residuals without transforming the equations. If movements of the endogenous variables within the VAR system reflect the effects of exogenous shocks or innovations, the VAR can be used to examine these shocks. Different shocks and their effects may be disentangled by placing identifying restrictions on the VAR.

Then a derived impulse response functions can give the response of birth and death rates (and therefore of population) to an impulse in wages. If there is a reaction of one variable to an impulse in wages we may call the latter a ‘cause’ of the former. This type of causality can be studied by tracing out the effect of an exogenous shock or innovation in wages on some or all of the other variables.

A problematic assumption in this type of impulse response analysis is that a shock occurs only in one variable at a time. Such an assumption may be reasonable if the shocks in different variables are independent. Eckstein et al (1984) in an early demographic-economic VAR study of Sweden 1749-1860 employ weather variables for this purpose. Shocks to weather affect other variables but are not themselves affected by shocks to wages or demographic variables.

Using the Wrigley and Schofield demographic series and the Phelps-Brown-Hopkins wage data, Nicolini (2007) finds that in England, contrary to the Malthusian model, positive checks disappeared during the seventeenth century and preventive checks vanished before 1740. In Germany Pfister et al (2010) from 1500 find a strong negative relationship between population and the real wage until the middle of the seventeenth century. On English data Moller and Sharp (2008) estimate highly significant preventative checks working through marriages, and agree with Nicolini that positive checks were insignificant. They suggest that growing population actually enhanced income by increasing the size of the market.

Crafts and Mills (2009) establish that wages ceased to be 'Malthusian' at the end of the 18th century, after which they grew strongly. They maintain that the preventive check cannot be found after the mid-17th century, as in Germany, but unlike Moller and Sharp they do not use a total marriages variable. Demographic growth was permitted by an expanding demand for labour of about 0.5 percent per annum. Crafts and Mills find no indication of positive feedback between population size and technological progress, contrary to the assumption of unified growth models (Galor and Weil 2000). For Sweden Eckstein et al (1984) are able to incorporate more variables into their VAR system, albeit for a shorter period than with the English data. They include infant mortality and a crop index as well as weather variables. As Malthus postulated, Eckstein et al estimate that a positive innovation in the general crop index, or in the real wage, increases fertility for several years and decreases infant and non-infant death rates over the same period.

For earlier periods some of the key variables indicated by theoretical discussion are not available as continuous time series. An example is human capital accumulation that drives technical progress, a vital component of many models (Bouccine et al 2003, Cervelatti and Sunde 2005, Lagerlof 2003, Galor and Weil 2000, Foreman-Peck 2011). One approach to this problem is the Kalman filter (Lee and Anderson 2002). This can be illustrated with the (initially) two equation Malthusian model – which has been shown to generate an equilibrium around a steady state population and real wage. Technical progress or human capital accumulation in effect shifts the *a* parameter of the demand for labour equation in the Malthusian model. Lee and Anderson model the behaviour of the disturbance terms $u_t$ and $v_t$, and the rates of shift of the parameters *a* and *c*. For expositional purposes, the simplest approach is to introduce only one more equation which explains unobserved H, human capital say, by a series of disturbance terms (summarised below by $\varepsilon_t$ and $\varepsilon_{t-1}$) reflecting other unmeasured factors.

$w_t = a + H_t - bP_t + u_t$

$P_t = c + d\, w_{t-1} + v_t$

$H_t = f\, \varepsilon_t + g\, \varepsilon_{t-1}$

All variables are endogenous in this system; it can be solved for each endogenous variable only in terms of lags and disturbance terms, because there are no exogenous variables. The second step is to use this system for prediction, beginning in the base period t=0, assuming $u_0 = v_0 = \varepsilon_0 = 0$. Starting values of all the six parameters (a-g) must be postulated. The third step is to update the prediction in the light of the 'new' data. Estimated $w_1$ and $P_1$ are compared with the actual values of $w_1$ and $P_1$ and new values of the six parameters chosen that maximise their likelihood.

This process is repeated for each period. When best estimates of all the model parameters are obtained, the effects of the human capital can be inferred from the values of *f* and *g* and the assumed unit effect on real wages. Lee and Anderson's (2002) parameter estimates are very similar to those from the Crafts and Mills' VAR (as noted above p7). Foreman-Peck and Zhou (2014) use a related approach to demonstrate a jump in the English female marriage age at the end of the fourteenth century and the effect on human capital accumulation over the ensuing centuries. Their method, unlike the Kalman filter, does not depend on distributional assumptions for the disturbance terms, but only requires that variables have first and second moments[14]. But most importantly for their purposes it enables them to estimate the economic-demographic model with different length time series, to use all the available information; the real wage series goes back to 1200 whereas the demographic series begin only in 1541.

***Conclusion***

Malthus' model of the pre-industrial economy in which increases in productivity raise population, but higher population drives down wages, appears to be a good description of much of demographic/economic history. The Western European Marriage Pattern - the late age of female first marriage, promised to retard the driving down of living standards by restricting fertility. Otherwise the positive check of mortality, induced by disease, war or malnutrition, constrained population in regions that had been long settled by arable and pastoral farmers, despite high birth rates. Living standards then largely depended upon how recently there had been mortality shocks. Cycles in the Malthusian economy may have been due to lags such as those in the response of fertility to wages, but shocks were perhaps more likely to be the drivers.

The demographic transition and the transition from Malthusian economies to modern economic growth has attracted many Cliometric models, but as yet no consensus about the process has been achieved. Population expanded most rapidly in the most dynamic European economies, so fertility restriction was not obviously the key. Yet the association of the Western European marriage pattern with economic development, combined with Malthus's emphasis on the vital necessity to balance population against resources, suggests there should be some connection. By the end of the nineteenth century there was a European pattern that towards the east mortality rates were higher and age at marriage lower than in the west. Mortality explained fertility statistically, and fertility explained age at

[14] Coefficients are not updated observation by observation as they are with the Kalman filter and the Kalman gain. Instead the recursive system goes all the way through the observations to get one vector of coefficients, minimising the square of the distance between actual and forecast values of the variables.

marriage, across English counties and across Europe. Time series behaviour was rather different because of lags in responses. French fertility control began at the end of the eighteenth century earlier than elsewhere in Europe. There population increased rapidly for perhaps a century, before fertility fell, with rising child costs and greater opportunity costs of time (in which children were intensive).

Human capital accumulation is frequently emphasised as the source of the breakout to modern economic growth, often helped by lower mortality that raised the rate of return or simply encouraged household choice for child quality. But the inability to measure human capital, other than by weak proxies such as literacy, has been a handicap. Nonetheless across Europe and across English counties literacy tended to be higher in countries with later female age at marriage, and there is some evidence that national outputs responded to greater literacy

Interactions between the economy and migration have been modelled with Cliometric structures closely related to those of natural increase and the economy. Similar problems arise with identification, of distinguishing cause from effect from contingent association. The historical focus of recent literature has, however, been different, even when bulk of the data has been available for the same period. Whereas the natural increase literature has been concerned with equilibrium and growth over many centuries, the bulk of the Cliometric migration literature has focussed on the great migrations from Europe of the later nineteenth century. These studies have yielded clear cut and conventional results compared with the longer period studies; wages were driven up by emigration from Europe and reduced in the economies receiving immigrants. Policies of migrant restrictions therefore must have influenced wages similarly, if they were effective. Over all economies involved, if migration was an improvement in resource allocation total output will have increased but it is unclear how these gains were distributed between source and host economies.

In the Malthusian economy there is strong evidence that population, or natural increase, did respond to higher wages. This encourages the expectation that subsidy policies like those attributed to the English 1601 Poor Law would encourage fertility of those subsidised, as Malthus feared. There is both evidence that this happened and that the 'social safety net' reduced premature deaths by breaking the link between harvest failure and mortality.

Figure 1

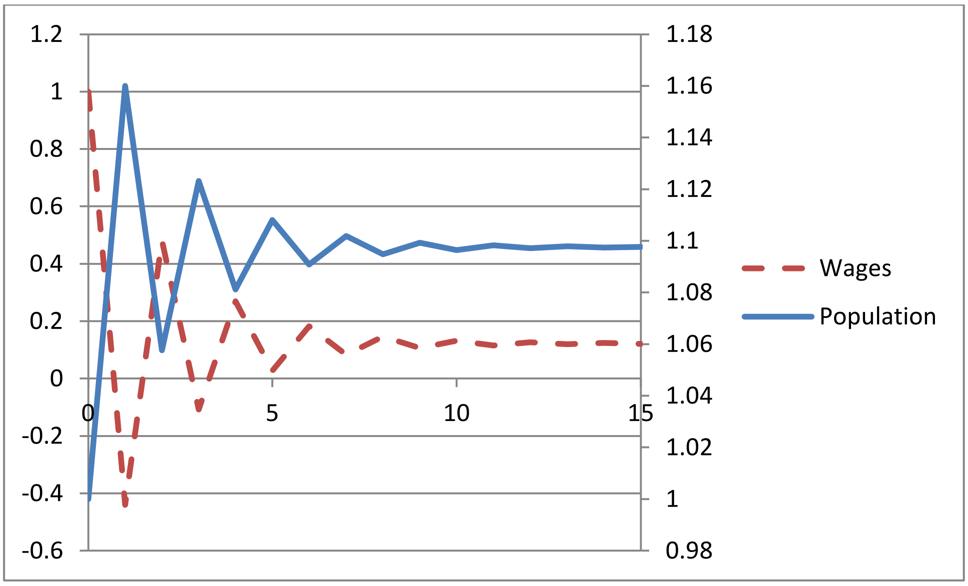



**Figure 2**

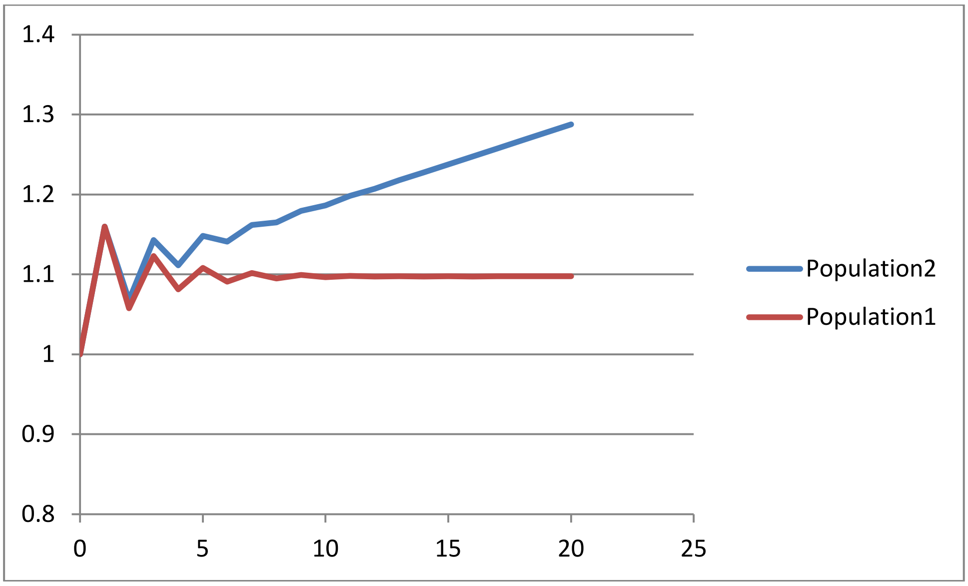
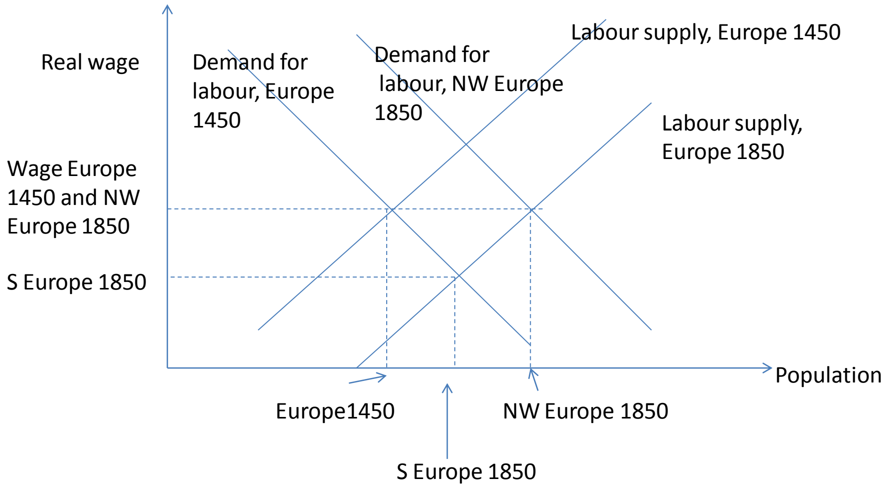


**Figure 3 Allen's (2001) interpretation of European divergence 1450-1850**

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