Understanding Growth in Europe, 1700-1870: Theory and Evidence

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Tentative outline

1. Introduction

a. Can theory help the historians?

In recent years, growth theory has turned to the Industrial Revolution and the emergence of modern economic growth as a topic of research. For economic historians, for whom these issues have been their bread and butter for over a century, this is a cause for jubilation. The issues are complex and difficult, and they need all the help they can get. What better than from the likes of Robert Lucas, Edward Prescott, Daron Acemoglu, Oded Galor, Charles Jones, and their colleagues, who have developed a set of novel and highly sophisticated and influential tools to analyze highly complex phenomena such as the interaction of demographic, institutional, and technological elements?

Theory has to simplify reality and to make assumptions. It tries to establish causal connections between exogenous and endogenous variables, to establish equilibria and the trajectories that a model of the economy will follow on its way there. What is being explained here is, at some level, rather straightforward. In the late eighteenth and early nineteenth century, income per capita, population size, technological sophistication, and a set of related variables, started to increase dramatically in a small number of economies in the northern Atlantic and European offshoots. In his long and detailed survey, Galor (2005, p. 177) has raised the main questions that he feels need to be answered, such as why there was so little growth before the great takeoff, why previous technological advances had not resulted in similar growth processes, and what the connection is between demographic changes and the growth spurts. Economic historians have raised other issues that need to be addressed here, and which play a lesser role in the models proposed by growth theorists: what was the role of formal and informal science (propositional knowledge) in triggering the growth spurts? what advantages did Britain possess that awarded it a leadership role, however ephemeral? what role did formal and informal institutions such as government and independent NGO's play in the process? what importance did colonial ventures and overseas trade, both short- and long-distance have in the process? how did the interaction between traditional sectors (agriculture and domestic industry) and the modern sector matter? Theory, it seems to us, can help us answer all of those questions by focusing on the variables that mattered and by pointing out likely and less likely causal connections, as well as by adding precision to the analysis.

But human history is far more complex than natural phenomena.[1] Theorists, by stripping away parts of the problem, are presenting an important and much improved way to solve the

[1] In one witty formulation, "God gave the easy problems to the physicists." (Lebow et al., 2000).

problem, but their models are not the magic wand that will solve the economic historian's difficulty. There are basically four reasons why unbridled optimism about the use of economic models in explaining the questions are probably out of place. One is the role of unobservables and intangibles. As economists have become increasingly convinced of the importance of culture in explaining economic growth (e.g. Tabellini, 2006; Guiso, Sapienza and Zingales, 2005), it is clear that our ability to understand large-scale historical events in single models involving measurable variables is somewhat limited. Second, economic growth consists of both shifts *of* the production function (that is higher productivity due to technological progress) and shifts *along* a production function (capital accumulation and improvements in allocation that increase output within a given set of techniques). The composition of growth between those is, however, unknown and the interaction effects between them make the story even more complex. Third, to the extent that the ultimate process is driven by technological progress, our understanding of economic growth will only be as good as our understanding of what *really* drives technology. To do so, we need a much improved understanding of the social and cognitive aspects of useful knowledge, the incentives and the institutions generating and disseminating innovation, and the political struggles between innovative entrepreneurs and conservative incumbents (Mokyr, 2002). While progress has been made on these matters, there is still much to be learned. Finally, leaving aside the difficulties in interpreting historical data, there is the lack of observations: the great transition succeeded only once. To be sure, there is a fair amount of cross-sectional variation between economies and regions that has been exploited a great deal, but there was only one Industrial Revolution, and if that phenomenon is to be taken — as it should — as the origin of modern economic growth, it really boils down to just one observation.

b. Unified models: pros and cons

Do we need a single theory to explain everything? Scientists still keep hoping to come up with a realization of Einstein's dream of a single TOE (Theory Of Everything). This has remained the holy grail of physics, and while it may one day be realized, it has not to date, and not for lack of trying. In biology, too, we do not have anything that resembles a TOE, Darwinian models notwithstanding, and it remains highly questionable if one will ever be found. If so, how likely is it that one will ever be found in economic history?

Perhaps the search is all that matters. Throughout the history of science, the world of knowledge has been enriched by both "hedgehogs" looking for a single TOE and "foxes," who were content to deal with smaller problems. It is fair to say that economic history has been mostly a land of foxes. The last (and possibly the only) great hedgehog was Karl Marx, whose TOE shaped the field for many decades, but it was not really geared to deal with economic growth, and had next to nothing to say about changes in demography and population dynamics. Yet an argument could be make that there is a fruitful conversation between hedgehogs who see a "big picture" and point to basic trends, and foxes who work on details, listen patiently to the hedgehogs and their grand theories, and then raise hard questions of detail and nuance, reminding the theorists of the complexities that are always greater than the models can deal with. Without the foxes, the hedgehogs' models and grand theories would be mere mirages and exercises in logic. Yet without the hedgehogs the work of foxes would possibly drown in a mind-deadening ocean of detail, without motivation or direction. It is this kind of complementarity that makes the scholarly conversation interesting and useful.

Yet we need more than that. Economic growth is the most significant event in modern history, and must be counted as one of the truly significant turning points in history, comparable to the emergence of homo sapiens or the rise of Christianity in the West. Understanding it, in the views of many, holds the key to the economic fate of humanity. As Robert Lucas wrote in 1988, once you start thinking about this [the differences in the level of economic performance], it is hard to think of anything else. In this search, a single "unified" theory of economic growth and demographic change must somehow aspire to satisfy the empiricists and details-people, immersed in the fine details of such mundane questions of whether the patent office really encouraged or discouraged innovation or the interactions between smallpox vaccination and other infectious diseases.

Unified growth is supposed to "unveil the underlying microfoundations consistent with the entire process of economic development" (Galor, 2005, p. 219). But at what level? Presumably these microfoundations must not only point to the human capital accumulation, technological advances, and the demographic changes that accompanied development, and productivity growth but also point out *how* they did so. These questions is still quite far from being answered. The development of dynamic models with latent state variables in which both the location and the stability of steady-state equilibria changes as a result of population change, while ingenious, have thus far proven to be difficult to verify historically. While they can reproduce a number of historically observed phenomena (such as the discontinuities in output per capita and non-monotonicities in fertility), they are far from the only way to account for these phenomena and they leave little room for institutions, political power, and beliefs to determine much except second-order differences in timing.

Secondly, unified growth is supposed to account for both pre-modern "stagnation" and the transition into sustained growth. Theories that account for just one of those periods are deemed to be ad hoc. But methodologically we could have had a regime change or "phase transition" as physicists call it, and separate accounts of the different regimes, so long as we could also explain the regime change itself. Such transitions and the difficulty in dealing with them, lie at the heart of the innovative attempt by North, Wallis, and Weingast (2006) to provide a "hedgehog" theory of institu-tional change. Above all, unified theories tend to contain an element of inevitability and "hindsight bias" that historians may find somewhat disconcerting. The potential for growth was already present in latent form in traditional society and its emergence was just a matter of time. This element of TOE is probably unattractive to historians who, like the biologists, know the importance of contingency and accidental factors ("path dependence" if one wishes) in determining final outcomes.

At the same time, however, the hedgehogs not only force the foxes to re-think their assumptions, they point to those issues that researchers should be working on. In this particular case, it is the connection between technological progress, the formation of human capital, and demographic change that has been at the center of attention thanks to work in unified growth theory (Lucas, 2002, Galor, 2005). Specifically, a great deal of emphasis has been placed on drawing connections between growth, technology, fertility, and the investment in education. Economic historians would clearly deny that this is *all* there is to the transformation, but by facing models that imply that it was, they are forced to rethink positions and dig for more data or examine afresh what they already have, and thus our understanding is advanced.

c. The riddles of growth: can we avoid Eurocentricity?

Historians have increasingly developed an antipathy to what they think of as "Eurocentric" history, that is the kind of history that places the West on the pedestal of the successful economic model of economic growth that other parts of the world needed to emulate. Such a history inevitably asks questions such as "why did China (or India of Africa) fail to be like the West." An entire literature has sprung up debunking this approach. Yet when all is said and done, by 1914 a gap had opened up between a club of economies that had achieved a high income per capita, and the correlates that came with that: longer life expectancy, more comfortable daily existence, and the kind of military potential that made Western dominance possible.

And yet it is arguable that the question why did China fail to develop is, indeed, illegitimate because what needs to be explained is not what failed to happen in China, India, Africa or the Middle East, but the European Miracle (Jones, 1981). In this interpretation, the evolution of the rich and industrialized economies in the West was a highly unlikely event, the result of a fortunate concatenation of circumstances. In this respect, it differs dramatically from unified growth theory where the seeds of economic success in the West were sown centuries before, and once they are there, growth is unavoidable. Unified growth theory is willing to concede that accident may determine the *timing* of economic growth, but that the event itself was wholly preordained from the day of creation. But how can we be sure? An alternative approach would stress the role of contingency and luck. Many things could have wrong in the European experience, starting with military events (e.g., the failure of the Mongols to devastate Europe after the battle of Legnitz in 1241), the fact that the Black Death killed "only" a third of the population but left the rest alive (unlike the demographic devastation of the indigenous populations of America after 1492), the failure of the counter-reformation to suppress the reformation, and the emergence of a free and competitive market for ideas in Europe (Mokyr 2006). The origins of economic growth in Europe, in this interpretation, far from being pre-ordained in the inevitabilities of unified growth theory, are a fluke of history. Once it happened, however, its effects on other parts of humanity were ineluctable. Whether one buys this interpretation or not may be a matter of taste; but there are few tests we can bring to bear to discriminate between it and the models of economic growth that imply that the roots of economic growth are to be found in European history long before it actually blossomed.

Either way, it is hard to avoid the fact that the history of economic growth is Eurocentric. This raises, of course, the question what it was about Europe that gave rise to the phenomenon. The answer is hopelessly overidentified: we have but one event, and yet we are facing a huge range of answers, from the religion-centered (Christianity was the only religion that was suitable to economic growth, as in Stark, 2000) to the geographically deterministic (Jones, 1981), to the superiority of European culture (Landes 1997). Yet, to date, growth theory has been of little help in answering that question.

2. The pre-industrial economy

Many formal models of historical growth assume that before 1800, there was no or negligible long-term growth (e.g. Hansen and Prescott, 2002, p. 1205; Galor and Weil, 1999, p. 150; Galor, 2005, p. 180). Some economic historians share this view (e.g. Clark, 2007). At some level, this statement is an oversimplification: there was far more dynamism in the pre-modern economies than is supposed by theorists.[2] There can be little doubt that in Gregory King's day (1688), income per capita in Britain was substantially higher than it had been at the time of William the Conqueror (Snooks, 1994). The growth rate may not have been high, but compounded over centuries, it changed historical reality. While growth was not yet self-sustaining, living standards in Europe were not at "subsistence levels" for most parts of the population, or even close.[3] Conventionally measured growth rates may be revised upward if they are computed in a more encompassing way. New products became available after 1600, and conventional measures of GDP tend to ignore both the appearance of goods not previously known, the value of variety, and quality improvements.

All the same, growth before 1750 was, if not totally absent, different in nature from what was to occur in the nineteenth century. Degree is everything in economic history, and a rate of growth of 0.1% or 0.2% is a very different phenomenon than one of 1.0%. Moreover, it was, on average, far less steady than it was to become after 1850, with periods of fairly rapid medieval expansion being punctuated with sharp and even disastrous declines caused by epidemics, wars, famines, and climatic events. Just as in the developing world today, slow growth was also volatile growth (Acemoglu and Zilibotti 1997; Cuberes and Jerzmanowski, 2007). Furthermore, pre-industrial growth was local or at most regional: some towns and small regions such as London, Antwerp, the maritime provinces of Holland, Southern Germany, Venice, and Tuscany experienced periods of high prosperity reflecting earlier growth; yet growth at the level of "the economy" or "the nation" was rare, and perhaps is a concept that should not apply, Adam Smith notwithstanding.

In pre-industrial economies, even when growth occurred, it typically led to forces that eventually extinguished it. Because of these "negative feedback effects", output increased in spurts – what Goldstone (2002) calls efflorescences. In contrast to similar episodes in the post-1820 period, these spurts did not last, as they normally created negative feedback that eventually extinguished growth. One mechanism of negative feedback were Malthusian forces, which caused rising per capita income to produce population pressure that eventually forces wages back down. An alternative explanation focuses on negative institutional feedback, with growth leading to an upsurge in the influence of rent-seeking that eventually causes stagnation.

a. **The Malthusian model: theory and evidence**

The economic history of the pre-1750 world is often referred to as the Malthusian epoch. It is characterized by a model that relies on two assumptions: one is that, some exogenous shocks excepted, population growth was governed by movements of income per capita. The other is that income per capita was negatively related to population size. Together, these two assumptions imply that whatever advances might be achieved by technological progress, capital accumulation, or gains from trade, they will inevitably be frittered away through the birth and

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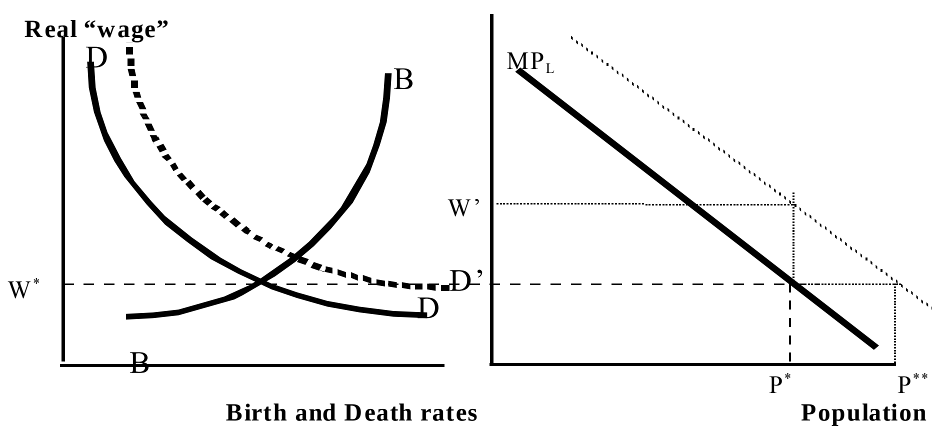
[2] Adam Smith had no doubt that "the annual produce of the land and labour of England... is certainly much greater than it was a little more than century ago at the restoration of Charles II (1660)... and [it] was certainly much greater at the restoration than we can suppose it to have been a hundred years before" (Smith, 1776-1976, pp. 365-66).

[3] Fogel (1990, 1994) argues that the bottom 20% of the population in France (and no group of society in Britain) were too short of nutrients to work long hours. The remainder enjoyed ample consumption opportunities.

survival of more babies.[4] In figure 1, birth and death schedules intersect at a wage W*. The technology schedule in the right-hand panel then translates this into a feasible population size P*. If a temporary shock drives the wage up to W', death rates fall, and population starts to grow. Eventually, because of declining marginal returns, this will force wages down to their previous level. In the more extreme versions of the model, this meant that little that could happen to these economies made much difference to wages or population size – demographic responses pin down the long-run equilibrium. As Clark (2007, ch. 2, pp. 22, 29) puts it, the Malthusian model implies that in the pre-industrial world technological progress produced "people, not wealth" and that "good government could not make people rich." Indeed, the stark implication is that under the assumptions of the fundamentalist Malthusian model, most of the engines of modern growth are impotent, since their gains are mercilessly dissipated by the growth of the number of mouths that need to be fed. The influence of the "iron-law" model on modern theorizing on the pre-industrial economy has been substantial.[5] Galor (2005, p. 180) acknowledges that there were substantial improvements in per capita income during the Malthusian period, but that accelerating population growth eventually reversed all gains.

Is the Malthusian model a good characterization of the pre-modern era? For the economic historian, one hard issue may well be to ask how much historical reality is reflected in

Figure 1: A Malthusian model



[4] In H.G. Wells's utopian novel, *Men Like Gods* Utopia in the past "spent the great gifts of science as rapidly as it got them in a mere insensate multiplication of the common life. At one time in the Last Age of Confusion the population of Utopia had mounted to over two thousand million..." (ch. 5 part 4).

[5] Lucas (2002, pp. 14-15) describes how he came to see the empirical power of this theory as its ability to account for the similarity in real incomes across different societies and the stability of living standards over time in the face of ongoing technological change. Others who buy into this model, in one version or another, include Galor and Weil (2000) and Hansen and

equilibrium conditions. If the time that it takes for the Malthusian model to work (i.e., to move from P* to P**) is a matter of generations, then the pessimist view may be a limiting condition and in the short and medium run progress may be possible and desirable. Furthermore, exogenous shifts of the D curve in fig. 1 may well lead to permanent improvements in living standards (as depicted by a move to D'). Oddly enough, an increase in mortality rates (given income) would achieve this result. The same would be true if fertility declined permanently, as would happen if the BB curve shifted to the left. The "iron-law" predictions depend crucially on the stability and slopes of the BB and DD curve. Thus, if there are substantial fluctuations in BB (due, say, to changes in marriage patterns) coupled to a fairly steep DD curve, the equilibrium real wage might differ a great deal over time and across nations.

In the end, this is a matter of the historical evidence. Mortality and nuptiality could adjust even over the short run. High-frequency events like famines, wars and epidemics had much smaller long-term effects than the disasters would suggest: a sharp decline in population was normally followed by higher wages. Within a few years, unusually high birth and low death rates would compensate for the initial decline in population (Watkins and Menken, 1985; Watkins and Van De Walle, 1985). Patrick Galloway (1988) demonstrated that, in many European countries, vital rates were responsive to grain prices in the way that the model predicts. Lee's original work on the Wrigley-Schofield population data showed nuptiality to respond (weakly, and with a lag that stretches credulity) to wages, but life expectancy to be largely independent of the wage. But the raw materials underlying these figures are imperfect, and there are serious conceptual and econometric difficulties in testing the model. Over the short run, movements in population before 1750 seem to offer resounding support for a Malthusian response.[6]

The problem is that stock variables like population size are invariably slow-moving – and so will the real wage be. The real wage data computed by Clark (2005, p. 1311) replaces the traditional wage series computed by Phelps-Brown and Hopkins and is based on a much broader array of commodities and a more comprehensive set of nominal wages. Both show the same, rather miraculous sharp decline of wages in Tudor England between 1495 and 1575, a decline that is accompanied by stable and then rising population as well as an unusually long life expectancy. Recent calculations by Allen (2003) and others have shown that in the long-term wages in Europe seem to follow very divergent trajectories. If there was an "iron wage", it was very different in north-west Europe than in the south or east. Furthermore, the advocates of Malthusian approaches often seem to conflate real wages with real per capita GDP or income. This is problematic because the participation rates may have risen and seasonal unemployment reduced, leading to a considerable rise in incomes per capita and per family even with more or less constant wages. Indeed, rising participation rates would, all other things equal, lead to real wages and real income per capita to move in opposite direction. The rise of cottage industries in the countryside after 1650, the famed "protoindustrialization" phenomenon, would do exactly that. There is also reasonable evidence to believe that the labor partipation rates were rising in the century before the Industrial Revolution (De Vries (1994); Voth (1998).

Another important problem in confronting the Malthusian model with the data is

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Prescott (2002).

[6] It Galor (pp. 183-184) shows some graphs that indicate that in pre-industrial Britain population and real wages moved roughly in opposite direction and that crude birth rates and crude death rates were negatively correlated.

endogeneity. Wages influence population size and vice versa. Without some source of exogenous identification, there is no hope of pinning down the size and importance of relationships. Recent work by Kelly (2005) suggests that weather may be a useful instrument for wages – the part of wage variation that is driven by it is not the result of a feedback from population. Estimated in this way, there is strong evidence that Malthusian restrictions bound in England before 1800, with marriage rates reacting strongly (and positively) and death rates strongly (negatively) to wages changes. Kelly's findings suggest that passing real wage fluctuations had a larger effect on nuptiality than on mortality. This implies that, in the short-run, the preventive check was stronger than the positive one, but both were significant. However, we would need to estimate a full model, with feedback from population to wages, to really confirm this finding. Cross-sectional evidence that richer Englishmen had more surviving offspring also appears to be consistent with the strength of Malthusian forces in early modern England (Clark and Hamilton, 2006).[7]

However, Malthusian constraints probably mattered more over the short- than the long run. Short-run demographic adjustments to real-income shocks may not imply that the "iron law of wages" held true. It is perfectly possible for the system to respond to high grain prices with increased mortality and reduced fertility, and yet not to be in a long-term stasis. In figure 1, the functions may be shifting so much over the longer term. At some point, if the death schedules, birth schedules, and technology function shifted enough, Malthusian factors will no longer be prime determinants of living standards – even if short-run fluctuations seem to suggest that this was so. Population was affected by long-term changes in background mortality, driven through mechanisms we only understand very partially as a result of exogenous variations in disease environment and climatic changes (Goldstone, 1991). If we are to believe the Maddison figures, all European economies in 1700 were both more populous and richer per head than they had been in 1500. One of the most spectacular cases is the Netherlands, where income per capita started to increase after 1500 with a corresponding population increase that lasted till 1650. But the population stabilized around 1650 with income per capita being at a level that in no way can be regarded as subsistence. De Vries and V.D. Woude (1997, p. 688) note that "by the end of the [sixteenth] century a conventional Malthusian model is no longer adequate to account for the economic and demographic dynamics... demographic forces interacted with the economy in ways far more complex than can be comprehended within a Malthusian model."[8]

The Dutch example suggests that, while the Malthusian adjustment mechanisms may have held in the short run, many interesting shifts were caused by other factors. Rising income has traditionally been associated with increased urbanization, to the point where the proportion urban has been taken to be a proxy for income per capita. European cities, unless Chinese cities, experienced different demographic parameters than the countryside, and had far higher mortality

[7] As Wrigley and Schofield point out, even if "for the individual it was better to be wealthy than to be poor if one wished to live long and be untroubles by infection... for society as a whole the balance of advantage was harder to strike. Increasing wealth bore an ambiguous relationship to improved mortality" (1997, p. 206). Yet not all cross-sectional evidence is consistent with a positive relationship between income and rapid population growth. In 1954, G. Utterström showed that poor and remote areas in Sweden nonetheless had lower death rates than the richer areas.

[8] Oddly enough, the richest economy in Europe is also one of the last to start experiencing the population growth that commenced elsewhere around 1750; in the Netherlands this did not begin until about 1815 (Hofstee, 1978).

rates. Not only that they were far more unhealthier places to live in under normal conditions (due to congestion and poor sanitation), they also were more vulnerable to the other horseman of the apocalypse, war (Voightlaender and Voth, 2007 Joachim: please expand this a bit?). Hence the curve D, which is a composite of rural and urban demographic behavior, could slope upwards *over some part of the w-D space* because of this composition effect. There could then be multiple equilibria: societies could fluctuate between one state where population was large, wages were low, cities small, and aggregate death rates low, and another one where wages were higher, cities larger, death rates higher, and population smaller. A major shock, such as the Black Death, could push the economy from one equilibrium to another. Moreover, the importance of cities is not only in that they increased mortality rates due to their unhealthy environment. They were also the locus for much of the commercial and inventive activities of the time – the loci of much international trade, of private-order institutions that supported the operation of the market, the generation of some new techniques, and the like. What this means is that at any level of population, income would be higher with a larger urban sector. All of this may have improved the economy's ability to sustain more people at the same level of per capita income over the long run. City growth may therefore have gone hand-in-hand with a slow, gradual outward shift of the technology schedule, making higher wages compatible with bigger populations. In this case, Malthusian forces could still dominate short-run changes, but the key *explanandum* would no longer follow from its basic tenets.

Some of the unified models also predict (modestly) rising living standards before the Industrial Revolution. This is because of "the inherent delay in the adjustment of population to the rise in income per capita, generated positive but very small growth rates of output per capita" (Galor 2005). In models such as Jones (2001), there is a similar, delayed response of population to technological advances. Given that total fertility rates for females in many pre-modern populations (and especially European ones) were substantially below their biological maximum, this is an unconvincing mechanism to explain why living standards drifted up, albeit slowly, in the centuries before 1800. Birth rates rebounded vigorously after a major famine — so clearly they could respond to rising living standards under the Malthusian assumptions. Where population growth depended on economic conditions, such as in the relatively "low pressure" demographic regimes characterized by the European marriage pattern, it remains unexplained why, over time, fertility would have been curtailed at progressively higher and higher levels of income – and that these restrictions broke down from the 1750s onwards.

In short, a substantial amount of evidence points to problems with the blind acceptance of the simple Malthusian model as the description of preindustrial Europe. While Malthus's model probably characterized some early part of pre-modern growth correctly, it is unclear how much the model applied by 1700. The theoretical literature that advances this notion must be concerned with the rather obvious cases in which Malthusian models did not hold or ceased to hold before the Industrial Revolution. There is no denying that demography provided a negative feedback in that growth led to higher nuptiality and fertility and lower mortality, and thus higher population. But this does not in and of itself suffice to show that it was sufficiently powerful to ensure that the iron law is an accurate description of the income dynamics of pre-industrial society.

b. **Institutions and growth: an alternative to Malthus?**

One alternative mechanism that generates reversals of fortune is institutional feedback (Mokyr, 2005). The particular idea is part of a broader class of models that sees political, legal and social factors as prime determinants of long-run growth. Predatory behavior and rent-seeking can produce negative feedback effects, with prosperity leading to a host of institutional responses that end up terminating the effects of technological progress or commercial expansion. The pre-modern economies faced the by-now classic "commitment" dilemma that the accumulation of wealth required on the one hand a strong government to protect it from foreign rent-seekers, such as invasions, strict mercantilist policies, or pirates.[9] Yet a powerful government itself could be the biggest rent-seeker or farm out its taxes to rent-seekers, break contracts, and seize assets. Ideally, a government should be strong enough to protect trade and property from foreign invasion, yet constrained in what it could do to its own citizens. This kind of combination, it has been argued, did not emerge until the eighteenth century (North and Weingast, 1989). Until then, rent-seeking (from abroad or from domestic rulers) time and again reversed the fortunes of those regions or towns that had managed to accumulate significant wealth. Examples of negative institutional feedback are not hard to find, and until we know more about their relative importance, accepting the notion that the economic outcomes before 1750 were mainly governed by demographic forces seems at least incomplete. Thus in early modern Europe, less-developed but large and militarily strong political units, such as the young nation states of Philip II, Gustavus Adolphus, and Louis XIV, threatened the richer but smaller city states of Italy, Germany, and the Low Countries. This military imbalance created a basic source of instability and inefficiency in the history of European cities. Economically successful but compact units were frequently destroyed by superior military forces or by the costs of having to maintain an army disproportionate to their tax base. The only two areas that escaped this fate enjoyed unusual geographical advantages for repelling foreign invasions – Britain and the Netherlands. Even these economies were burdened by high taxation, the cost of surviving in a mercantilist world based on the notion that the economic game between nations was zero-sum, and that foreign trade was a servant of political and dynastic interests.

If the institutional feedback mechanism turns out to have been important in the pre-1750 world, it would shed a very different light on the emergence of modern economic growth and its roots. Much of the modern theoretical and literature assumes that what has to be explained is the transition from a Malthusian to a post-Malthusian regime. In that story, demographic and technological elements are modeled in various ways we shall see below. However, if the constraints on growth before 1800 were as much institutional as they were demographic, the story will have to be amended in important ways.

Most interpretations of early modern Europe do no focus on this negative feedback mechanism to explain the intermittent nature of growth. Instead, the story is one of constraints that falling away first in some parts of Europe, then in others. The single best-known statement in this tradition was formulated by North and Weingast (1989).They argued that the Glorious Revolution and the Bill of Rights in England did more than put government finances on a firm footing. Because of the changes in the role of parliament and the increasing power for common law courts, the monarch's power had been very effectively curtailed and was widely viewed as

[9] Moreover, as Epstein (2000) has argued, centralized nation states solved certain coordination problems that societies with heavily dispersed powers could not resolve, without which modern markets could not have evolved.

such through credible commitment. High-handed breaking of contracts and seizure of property came to an end.[10] North and Weingast argue that, once property rights had been firmly established, risk premia fell. Capital accumulation took off, and investing in new ideas became much more profitable. Eventually, Britain's growth rate took off. Many scholars have taken issue with this interpretation. Clark (1988) showed that interest rates on *private* instruments such as rent charges did not fall after the Glorious Revolution. Stasavage (2002) looks at public interest rates more closely and argues that the new settlement was not stable for a long time, and that interest rates were as much determined by partisan politics as they were by constitutional change. Sussman and Yafeh (2006) argue that wars and the threat of revolution mattered a great deal for British interest rates, and that the new Hanoverian regime was far from firmly established after 1688.

Following the work of North and Weingast, numerous scholars have tried to use institutional analysis to explain the divergent growth records across early modern Europe. DeLong and Shleifer (1993) return to the argument in Montesquieu (1748) who famously argued that growth was likely to be more vigorous in Republican states which did not suffer arbitrary interventions by the authorities.[11] They argue that absolutist rule was harmful because of three reasons – centralized powers run by ambitious, powerful princes fought more wars, taxed more comprehensively, and respected property rights less. Autocratic states also happened, on average, to be further away from the new trade routes to the Americas and Asia. Only one of these channels is directly associated with the institutional interpretation in its narrow form, and Delong and Shleifer cannot show that it is particularly potent. This theory is supplemented by Acemoglu, Johnson and Robinson (2005), who argue that two of the channels identified by Delong and Shleifer interacted in a particular fashion to strengthen institutions. Countries that had opportunities for Atlantic trade experienced a gradual strengthening of bourgeois forces in society. Hence, their measure of "constraints on the executive" in Britain and the Dutch Republic grew, making it easier for these countries to overtake other European powers during the 17th and 18th century. They also demonstrate that this improvement in the quality of institutions mattered for growth – urbanization rates surged wherever geographically-determined "exposure" to the Atlantic trade was high.

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[10] These had previously been possible both through the legal system – namely the Star Chamber – and brute force (such as in the raid on the Tower of London, when the gold of goldsmiths was seized).

[11] "An opinion of greater certainty as to the possession of property in these [republican] states makes [merchants] undertake everything.… [T]hinking themselves sure of what they have already acquired, they boldly expose it in order to acquire more…".

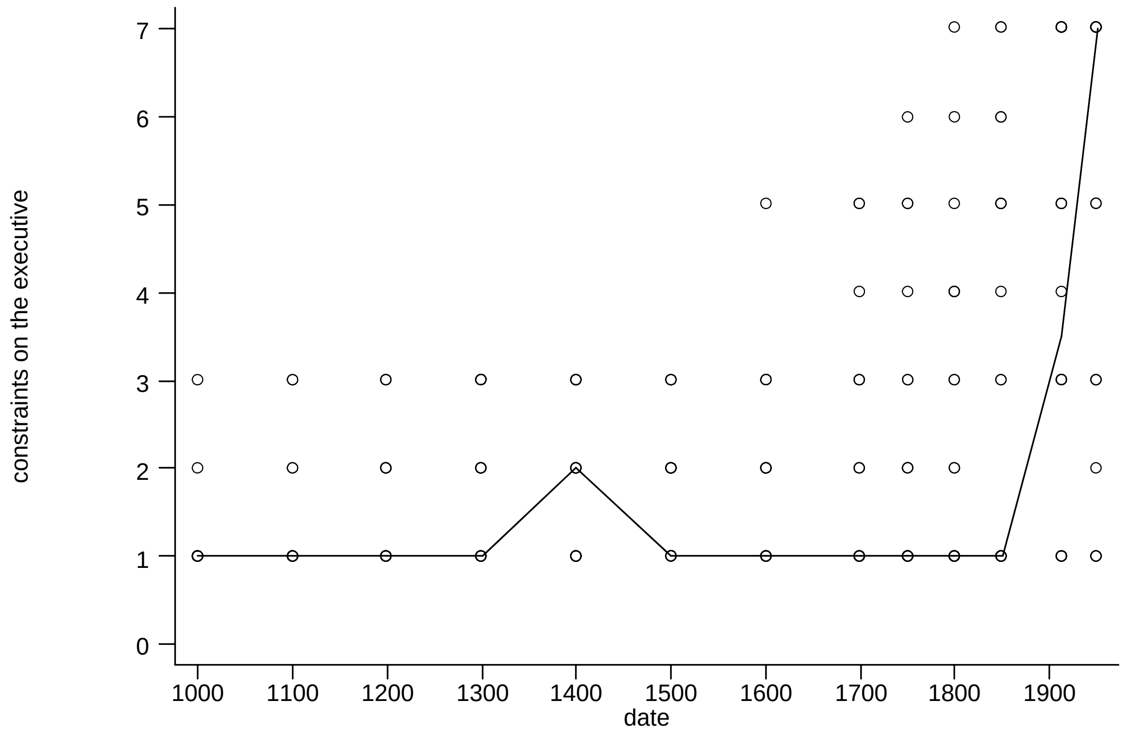

Figure 2: Dispersion and Median Score, Constraints on the Executive, Europe 1000-1950 (line shows median)
Source: Acemoglu et al. 2005

Institutions have thus gained a great deal of credence in the modern growth literature and economic historians clearly have been at the forefront of restoring them as a central actor on the stage of economic change (Rodrik et al., 2005; North, 2006). Yet interpretations of Europe's growth record that rely on institutions face as many difficulties as does the Malthusian Model. To start with, the exact definition of institutions remains a matter of some dispute. North defined them as "a set of rules, compliance procedures, and moral and ethical behavioral norms designed to *constrain* the behavior of individuals in the interests of maximizing the wealth or utility of principals." Greif (2005) wants to include other modes of behavior that create historical regularities. In Greif's model, beliefs and ideology act as "deep" parameters that determine the efficacy with which society will set up the rules that make exchange and investment possible. Yet there are few good theories that explain in detail how institutions change and why some economies end up with "better" ones than others. Standard measures in the literature such as the (perceived) risk of expropriation, government effectiveness, and constraints on the executive – can all easily reflect choices by governments, and may change quickly. For any theoretical model that sees better institutions work wonders through capital accumulation, this would be problematic. Glaeser et al. (2004) show that all three standard measures of institutions often change after a single election. Presumably, property rights that are simply protected because of a dictator's whim are not worth a great deal. The volatility of these measures over time makes it less likely that they identify some structural parameter of the political system. Other, more obvious variables such as judicial independence, proportional representation, and constitutional review, vary much less and are more likely to proxy for the structural constraints on governments that North had in mind. Yet in modern-day data, the effect of these variables is small and insignificant. What is needed is a "deep" parameter of a country's political constitution that does not change quickly, and that is not simply a reflection of current economic and political conditions.

For early modern Europe, the "constraints on the executive" variable compiled by Acemoglu et al. successfully predicts urbanization rates. By itself, this variable does not explain whether institutions will be successful . States with extensive checks-and-balances, such as Venice, the Holy Roman Empire and Poland, indeed placed very considerable constraints on a monarch's freedom of action, and continued to do as long as they continued to exist. Yet they did not become hothouses of economic dynamism. Other states in which the absolutist agenda was successfully carried out, saw a significant reduction in the number of hurdles placed in the path of a prince's wishes.[12] Even for that epitome of absolutist rule, the Sun King Louis XIV, historians have largely rejected the idea that his rule can meaningfully be described as an implementing a successful, far-reaching absolutist agenda. For a generation, a new consensus inspired by the works of, inter alia, Georges Pagès and Roland Mousnier (1970) has emphasized how much French kings at the height of absolutism still governed through social compromise and consensus, maintaining the stability of a traditional society and the influence of old elites for much of the time. Even if revisionism along these lines has gone too far, as some have argued – it seems doubtful that the currently available classification schemes capture enough of what is directly relevant to the argument that institutions and restrictions on executive caused economic growth before 1800.[13]

One question is about identification: one relationship between power and economic development specifies that an economy will develop if the government can commit to respect property and contracts, and that this commitment is made credible by placing adequate constraints on the government's power. However, it is richer and more developed economies that countervailing power centers could emerge. Moreover, power and military capability were an important factor. War was often an important catalyst of these changes – in Tilly's memorable phrase, "states made war, and war made states." Where constraints on the executive were far-reaching, such as in the Italian Republics, military successes could be few and far between and foreign invaders were able to destroy much of the wealth, in the classic pattern of Olson's "roving bandits." In modern data, there is a robust, negative correlation between military conflict and political instability on the one hand, and growth on the other (Alesina et al. 1996). Constraints on the executive, carried to the Polish extreme, were not conducive to economic development – not least because they could contributed to the disappearance of the state itself at

[12] From the sixteenth century onwards, the Polish Sejm had extensive powers over taxes, legislation, foreign policy, and the budget. Since 1505, the king could not pass legislation without support by the Sejm. From the end of the sixteenth century, majority voting declined, and the unanimity principle began to be followed. German Emperors had little direct power outside his own territory. Implementing any kind of new policy required the co-operation of the princes that ran most of the Empire. Getting legislation through the Reichstag, the imperial assembly (consisting of the prince-electors, of dukes and other princes, as well as the imperial cities), was very difficult. In 1648, the Emperor became formally bound to all decisions of the Reichstag. It is hard to think of stricter rules to bind a head of state. Yet German urbanization and income growth rates largely stagnated, at least after 1600.

[13] For a recent critique of the revisionist argument, cf. Beik 2005.

the end of a sequence of grueling military defeats. A fundamental trade-off was thus created: a powerful central government was more effective to protect an economy from foreign marauders, but at the same time the least amenable to internal checks and balances.

The example of the Venetian Republic is also instructive. In terms of its institutional setup, it hard to think of a political entity that would more closely approximate the modern ideal. Property rights were well-protected. Doges were elected officials, theoretically for life; in reality, subject to good performance. A patent system was in place as early as the fifteenth century. Yet despite its early riches and success as a sea power, Venice declined both as a military and as an economic power. Few doubt that the events following the League of Cambrai (1516) were directly and indirectly responsible for the demise of Venetian power and the eventual decline of its prosperity. Today, constraints on the executive go hand in hand with lower probabilities of military conflict, as democracies are unlikely to go to war with each other (and tend to win in wars against non-democratic powers). In the early modern period, the correlations probably had the opposite sign. The political entities with highly effective constraints on the executive quickly became victims of outside powers whose rulers operated without being hamstrung by domestic opposition. The Thirty Years War, made more brutal and protracted by outside intervention, ravaged the Holy Roman Empire of the German Nation; Poland disappeared at the hands of Austria, Russia and Prussia; and the Northern Italian Republics declined as outside powers – notably France, Spain, and Austria – increasingly intervened. For early modern states, political stability and a chance to escape being a victim of outside aggression may well have depended on pursuing an absolutist strategy. The effect of "constraints on the executive" on growth will hence be a composite of the (positive) effect for property rights, as well as the negative effects through the continued influence of rent-seeking groups, and the (similarly negative) effects of political instability and military defeat.

Moreover, the modern concept of "constraints on the executive,"signifying the protection of private property from the predatory tendencies of a monarch, was different from those in early modern Europe. The constraints on many monarchs in 1500 were real enough. They probably, on average, did not increase in Europe until 1800, and probably declined significantly in some states. Yet most of these constraints took the form of rent-seeking groups ensuring that their share of the pie remained constant. None of the groups that offered resistance to the absolutist agendas of rulers in France, Spain, Russia, Sweden, and elsewhere were interested in creating growth – nor did they ensure that sensible, long-term policies were enacted. Put another way, if the Pagès and Mousnier revisionism is right, then French absolutism failed in economic terms largely because it did not succeed in implementing much of the absolutist agenda because it was unable to control special interests. As part of their struggle to field ever larger military forces, the modernizing states of Europe had to overcome the interests of powerful groups within society,. Large parts of Europe's early modern history read like one long tale of gridlock at the hands of interest group from local lords to the church and the guilds.

It could be argued, moreover, that the literature on institutions in pre-modern Europe has unduly concentrated attention on the state and formal institutions, and neglected the entire issue of non-state institutions, both formal (in the form of corporations and other early NGO's) and in the form of social norms and reputational mechanisms, which allowed for order without law. If, as the institutions literature argues at a fundamental level, respect for property rights and recourse to due legal process are key for economic development, then we need to construct variables that more closely capture this dimension. A more comprehensive and historically meaningful set of indicators should measure effective, legal or customs-based constraints on the actions of the executive or of local power groups – anything that makes it harder for might to be right, without due recourse to the law. Opportunistic behavior leading to Pareto-dominated equilibria could be overcome by a host of mechanisms (besides the standard of third-party enforcement) in which members of select groups were able to establish their trustworthiness through a variety of costly signals (Greif, 2005) and play cooperatively. The modern literature on institutions has shown that such arrangements may still have a fair amount of explanatory power today (Ellickson, 1991; Posner, 2000). They need to be investigated for periods not covered by Greif, and their significance relative to that of formal institutions such as Parliament. We shall return to the importance of informal institutions below.

c. Culture, class, and natural selection

Since Max Weber's work on the spirit of capitalism, culture is one of the "usual suspects" that may determine wealth and productivity. Modern scholars (e.g. E.L. Jones, 2006, pp. 126-132; Temin 1997) have concurred. The problem, of course, is that culture means different things to different scholars. Culture may be subject to evolutionary forces (e.g., Boyd and Richerson, 1985). Galor and Moav (2004) offer a model in which the crucial state variable that changes during the pre-industrial period is not just population size, but "human quality" (genetic or behavioral). Households endowed with more desirable human characteristics (education, the right genes, economically beneficial attitudes) produce more surviving offspring and gradually but ineluctably change the composition of the population. Therefore, the quality of the human population drifted up prior to the Industrial Revolution. But disentangling "inherent quality" from changes resulting from responses to changing incentives seems a formidable challenge. Also, natural selection normally need not increase quality at all; it simply is adaptive to existing circumstances but utterly myopic, so that it is easy to see why it may not result in any improvements. Given that humans normally only start to reproduce in their late teens or early twenties, any process that relies on natural selection requires a very long time-span – or strongly divergent fertility rates.[14] The Galor-Moav approach has recently received some qualified empirical support Clark and Hamilton (2006) found that the rich and literate in early modern England fathered more surviving children. Whether natural selection improved in some definable dimension the quality of the population in the countries about to break out of the Malthusian model before the 1700's is still far from an established fact.

Modern research on "culture" and economic development (e.g., Tabellini, 2006; Guiso, Sapienza, and Zingales, 2006) shows an exogenous effect from culture to income and that culture has a lot of persistence. Here culture is defined above all in terms of the values and beliefs of individuals. While trying to control as much as possible for endogeneity, these studies still show that when people trust one another, believe that if they work hard they will get ahead in the world, and that on the whole the formal institutions of power in the country are not threatening

[14] Given that the earliest data are from the 16th century, there were only approximately 5-6 generations over which we can be reasonably certain that this selection effect might have worked – not a great length given the modest reproductive advantage. All the same, recent genetic research has suggested that "evolutionary changes in the genome could explain cultural traits that last over many generations as societies adapted to different pressures" (*New York Times,* March 7 and March 12, 2006).

them, economic progress will ensue. We have no record, of course, of such poll-based data for historical times, and so there is no easy way that such findings can be reproduced. But the importance of private-order institutions, that is, the kind of arrangements that made people keep their promises and behave in an honorable way because they had realized that opportunistic behavior was not a dominant strategy in iew of the reputational damage that such behavior would entail, seems quite striking. In this interpretation, the middle classes of commercial societies adopted a more cooperative mode of behavior, leading to Pareto improvements. The focal point in such equilibria may well have been what middle class people perceived as "gentlemanly behavioral codes," which is to signal that one belonged to a class that was sufficiently disinterested in money that they would not cheat a partner (Mokyr, 2007). It may well be that such social norms were far more important than third-party enforcement of laws and contracts in the support of European markets.

But whence such middle class values? In an innovative paper, Doepke and Zilibotti (2007) have produced a model of class formation through the endogenous formation of inheritable preferences. They argue that the rise of a bourgeois elite in industrializing Britain may be regarded as a surprise. Before the transformation got under way, aristocrats had all the odds stacked in their favor – available funds, political connections, access to education. Yet few members of the old political elite actually got rich in manufacturing after 1750. Doepke and Zilibotti argue that this is because other groups of society – the middle classes – had accumulated a larger stock of "patience capital", that is, a host of cultural practices and norms that make the delay of immediate gratification accepted and expected. The intuition here is that artisans need to defer gratification because it takes a long time to accumulate human capital (that is, to complete the training needed to become a craftsman). On the other hand, the old aristocracy taught their children how to enjoy leisure and thus provided them with a culture that worked against both hard work and investment. Through centuries of careful saving and investing, the middle class built up both financial capital and valuable cultural traits. As the new technologies of the Industrial Revolution suddenly offered greater returns to patience, the groups best-placed to exploit them were not the elite but those with steep earning profiles, that is to say, those who would do well in mid-life if they invested in themselves as lads. Those people had to acquire patience capital, and it is this kind of culture that played a central role in the subsequent development of capitalist industrialism. In their story, the *absence* of functioning credit markets is a key element in the story – only when financial markets are segmented do returns to patience (adjusted for risk) differ across groups. They apply their model to the decline of the aristocracy in Britain, generating an impressive fit overall between their predictions and historical fact.

Yet the concept of patience capital arguably holds even greater promise. It may be no accident that the "nation of shopkeepers", as Adam Smith called it, became the first to industrialize. It offered an environment in which bourgeois values and practices flourished and gained in relative importance. Clark's and Hamilton's result that wealthier Englishmen had more surviving children could suggest that, instead of leading to an upward drift in some unmeasured, unnamed indicator of human quality, it simply enlarged the relative size of those who had learned to save (and invest), and those who passed such values on to their offspring. Such a change in population composition would also have contributed to the decline in English interest rates since the Middle Ages (Clark 1988), from 10-11 percent in the 13th century to 4 percent by the 18th. A gradual increase in savings, caused by compositional effects attained through the increase in the relative number of those who were more patient, would be an alternative to the theories that attribute the rise in savings to the "Calvinist ethic." The tendency of interest rates to decline in stable and prosperous countries, as noted by Adam Smith in the case of Holland, may not necessarily indicate that technology was stagnant and returns to capital diminishing rapidly. It may simply be that patience (and financial intermediation) was growing faster than savings could be usefully recycled into investments.

Compositional change can also help us understand evolving demographic behavior. Behavior often differs across subgroups, as both historians and economists have found.[15] Given that many more children could have been fed, and that the constraints on fertility behavior were mostly social and cultural (working through nuptiality rates), it is easy to see how evolving norms could have changed population growth rates. Differential fertility behavior and evolutionary mechanisms might thus explain how and why the Malthusian regime came to an end. In the Galor and Moav (2002) model, for example, this is depicted as the gradual increase of the number of people with a strong preference for "high-quality offspring." As yet, we know far too little about the relative differences in reproductive behavior (as manifested, for example in different marriage ages) and economic success in early modern Europe. Compositional change may have played a large role, but at the current stage, it is hard to tell. What is needed is more evidence along the lines of the material gathered by Clark and Hamilton documenting differential fertility over the long run.

If Europe saw a rise of bourgeois values prior to the Industrial Revolution in terms of savings behavior, it was complemented by a rise in work intensity and the length of the working day, and the growing orientation on the market at the expense of self-sufficiency. DeVries (1994) termed this change the "industrious revolution". By the eighteenth century, even Catholic rulers were abolishing holy days to boost labor input in their economies. Clark (1987) found evidence that work intensity in the most economically advanced parts of Europe was much higher than elsewhere. Voth (1998, 2001) argues that the work-year in Britain was already a long one by 1750, and that it increased yet further as a result of a decline in festivals, holy days, and the practice of taking Mondays off ("St. Monday"). Such changes are perfectly consistent with the model proposed by Doepke and Zilibotti, in which those with relatively low "leisure skills" became the dominant classes.

d. Long-run changes in the European economy before the Industrial Revolution: underperformance or undermeasurement?

Before the eighteenth century, there are few output measures that could help us reconstruct production per head. What we have instead are wage series as well as prices, plus some scattered information on rents on land and the like. The GDP figures compiled by Maddison and others are essentially based on these wage series. Even the better ones rest on distinctly shaky foundations. Allen (2003) is one of the more recent attempts to offer new and better series. Yet wage information is still overwhelmingly skewed towards urban workers – a small part of the population at best. Price indices are dominated by food items, and grain in particular. We have very little information on the price or quality of clothing, of rents, and other

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[15] In addition to Clark and Hamilton (2006) cited above, we may mention the work by Herlihy (1997, pp. 56-57) and Galor and Moav (2002).

essential items. As a result, some new revisions imply changes in living standards over a century that are only half as big as earlier series suggested (Clark 2005). Among the difficulties that surround the interpretation of these wage data, two are paramount. One is the difference between annual earnings and daily wages — the difference being the number of days worked per year, a function of many factors, not least the ability of the economy to find employment for workers who were facing seasonal fluctuations in labor demand. The other problem, rarely touched upon by those collecting wage statistics for earlier times, is that a proportion of the wages were paid in kind, either in the form of the product that the workers made or in the form of meals and other services provided by the employer. The proportions of wage-in-kind differed across space and over time, and without taking them into account, the data collected by Allen and others remain tentative.

Yet even if we had perfectly measured wages and prices for consumption bundles of early modern populations, we may be underestimating changes in living standards by an order of magnitude. The main reasons are unmeasured quality improvements in goods and services and the value of variety. As Nordhaus (1997) has demonstrated in the case of lighting, big efficiency gains as a result of new technology are often missed by traditional ways of measuring price changes. Increasing variety may have brought benefits every bit as big. Trade, both long-distance and local as a result of higher population densities and better communications, broadened the range of goods available to the vast majority of Europeans. Between 1500 and 1750, Europeans of all social classes began to consume large amounts of sugar, tea, cod, tobacco, cocoa, porcelain, and cotton goods. Potatoes and maize made important changes in the staple diets. The effects of the range and variety of goods available in the present-day US has been estimated to have boosted living standards by the equivalent of a fall in prices by approximately 30% over the last 30 years (Broda and Weinstein 2004). Even the comparatively modest trade before 1800 expanded the range of available goods greatly, boosting living standards far more than GDP indicators show.

3. The first transition: from a Malthusian to a new economy.

Whether Europe in 1700 was still in the grips of a Malthusian regime, properly defined, is thus open to question. In many regions, and over longer periods, population and living standards had started to move up in parallel. In any event, by the late eighteenth century the Malthusian regime had broken down. The timing and location of the transition, from a "traditional, slow-growth" society to a more dynamic society is have been the main focus of modern unified growth models and it has by general consensus been identified with the Industrial Revolution. Yet the interpretations of the causes and nature of the Industrial Revolution offered by these models differ quite a bit from one another. Exogenous growth models treat the transition as basically pre-determined by technology. In Galor-Moav, Jones and others that use endogenous growth based on population size, technological change boosts population size, which then produces ideas with greater frequency, and so population size and technology interact, often in intricate ways.

The rapid rise in population after 1750 in many European countries was to mark a far more dramatic departure from earlier patterns. At the same time, output started to grow – living standards remained constant or even increased slightly, where earlier patterns would have suggested a collapse. This is the phase that Galor has termed the "post-Malthusian" phase. We follow this approach of dividing the Industrial Revolution as conventionally defined into two phases – an early phase when population size no longer determines living standards but living standards seem still to be more or less stationary, and a later, "Solow"-phase when technological change becomes rapid and is largely translated into higher living standards.

a. The meaning of the Industrial Revolution

Leaving long-term economic stagnation behind can be modelled either as a sudden discontinuity with the past, or as a gradual acceleration over the very long run. In part, the difference is one of framing the time span appropriately – compared to what happened in the millions of years since homo sapiens left the African plain, developments after 1750 were very rapid indeed. If we focus on changes over decades, the pace no longer seems very impressive – at least compared to, say, growth rates after 1945. The discontinuity par excellence is the Industrial Revolution, but how should modern growth economists interpret it?

The Industrial Revolution remains a pivotal event in the historiography of the beginning of economic growth but its interpretation has changed considerably since the term was first coined two centuries ago. It was not the beginning of economic growth as such. It is now quite clearly accepted that economic growth did not start during the Industrial Revolution, and that its macroeconomic effects did not become discernable until the second third of the nineteenth century. In part this is to be explained by the fact that at first the Industrial Revolution affected only a small sector of the British economy and that most economic activity still took place in slowly-changing "traditional sector" even if the weight of the rapidly-growing modern sector was increasingly rapidly and the exact boundaries of these two sectors remain in dispute. To this arithmetical truism we may add the fact that the first Industrial Revolution was accompanied by three unrelated phenomena that temporarily depressed economic growth, namely almost continuous war from 1776 to 1815 (with a brief respite in the decade after 1783), the rapid growth of population that, in addition to increasing overall population size, also increased the dependency ratio, and finally the succession of poor harvests and high grain prices that struck the British economy between 1760 and 1816.

Despite the absence of growth itself, however, the Industrial Revolution represents the transition from the slow-growing economy of the early modern period to the faster growth of the post 1830 period. In one classic formulation, it was neither the age of steam, nor of cotton, nor of iron, it was the age of progress. Technological progress took place over too many fronts to be simply waved off as a local fluke in the cotton industry, as some historians (Clark) have done. What mattered above all was not so much the famous "wave of gadgets" of the 1760s and 1770s, but the fact that the process of technological progress did not fizzle out once it had settled on a number of successful designs. It is perfectly possible to envisage a world in which technology had crystallized on such successful techniques as mules, puddling and rolling furnaces, and stationary low-pressure steam engines settling down at a new, somewhat higher, technological equilibrium. That this did not happen is the key to the emergence of modern growth, even if that growth came properly speaking after the Industrial Revolution was complete.

A full explanation of this phenomenon cannot be attempted here (but see Mokyr 2006, 2007). The summary is something as follows. The Industrial Revolution, though it took place first in Britain, was really a Western European "joint project." British inventors collaborated with inventors and scientists from the European Continent and North America. In doing so, the Western World depended on changes not only in economic circumstances such as a higher living standard and a more commercially integrated environment in 1750 than in 1500, but also on changes in the mind-set of its elites. Among those changes in mind-set, the Enlightenment of the eighteenth century is central. The Enlightenment advocated explicitly changing the agenda of scientific research to suit the needs of the economy. In this endeavor, the inspiration came from the Baconian program, implemented first by the Royal Society and subsequently by scores of organizations, academies, and informal groups. Moreover, the Enlightenment movement explicitly advocated the dissemination of knowledge to those who might be able to use it best, through books as well as through informal contacts in which tacit knowledge could be transferred. As a result, the connections between people of science ("natural philosophers") on the one hand and inventors, mechanics, and engineers on the other was much closer in 1820 than it had been in 1680.

Moreover, the Enlightenment brought about a slow but indisputable fading of the rent-seeking institutions of the *ancien régime*. By 1820 rent-seeking had been sufficiently weakened that the institutional feedback discussed above was made inoperative. European nations that were getting wealthy were no longer in fear of being invaded by a predatory power, and within most western countries, governments were constrained in the amount of resources they could expropriate from their citizens. Moreover, exclusionary organizations such as guilds, monopolies, or rent-creating obstacles such as internal (and increasingly external) tariffs were weakened during the first half of the nineteenth century. This triumph of liberal politics inspired by classical political economy — the Enlightenment's proudest offspring— no matter how temporary, was necessary to lift the West over "the hump".

It is a somewhat separate literature why this process started in and was most successful in Britain. Britain was peaceful (at least in the sense that no fighting took place on its soil) and it had a government that had discovered a way of changing institutions peacefully through the emergence of meta-institutions that could change the rules of the economic game legitimately (in the sense of them being accepted even by those at the losing end of the stick). To that we can add the fortunate resource situation in Britain such as the availability of high-quality coal, and the presence of a substantial cadre of highly skilled craftsmen on whose technical dexterity the implementation of new techniques depended. Its more conducive political climate and the existence of complementary resources ensured that Britain could take advantage of its own inventions as well as those of others.[16]

Yet this advantage was temporary. By mid century, when this process had run its course, the gap between Britain and the Continent began to show signs of narrowing, yet instead of Britain being pulled down to the slower rate of development of the Continent, the growth of income began to spread to the rest of Western Europe. By that time modern economic growth,

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[16]The Swiss visitor de Saussure had noticed already in the 1720s that "English workmen are everywhere renowned, and justly. They work to perfection, and though not inventive, are capable of improving and of finishing most admirably what the French and Germans have invented" (de Saussure, 1902, p. 218, letter dated May 29, 1727). David Hume [1758, (1985)], p. 328 pointed out (with some exaggeration) that "every improvement which we have made [in the past two centuries] has arisen from our imitation of foreigners... Notwithstanding the advanced state of our manufacturers, we daily adopt, in every art, the inventions and improvements of our neighbours."

rapid and sustainable, could truly commence.

b. Endogenous growth: did size matter?

Early models such Kremer's (1993) paper modeled the transition from "Malthus to Solow" as one long, gradual acceleration of growth rates. Kremer's model assumes that more people spell faster technological change since the probability to have a bright idea is more or less constant. Kremer showed that some of the basic predictions derived from such an endogenous growth model driven by population size hold both over time and in cross-sections – since one million BC, growth rates of population can be predicted from the current size of the population. Also, geographically separated economic units with greater surface areas produced bigger populations and higher densities. Demographic transitions, with fertility responding negatively to higher incomes above some threshold level, avoid the model from exploding. This assumption is also critical in the dynamics of Galor and Weil (2000) where any technological change in the Malthusian world leads just to population growth, but once population exceeds a critical level, it begins to change the model's equilibrium. Yet a direct nexus between population size and technological progress is historically problematic.

As Crafts (1995) has pointed out, the implications for the cross-section of growth in Europe are simply not borne out by the facts – bigger countries did not grow faster.[17] Modern data show very similar patterns: country size seems to have a negative effect on one of the most reliable correlates of economic growth, the rule of law (Hansson and Olsson, 2006). Joachim: can you complete this section on size matters with some reference to this Alesina book? Even if we substitute population with factors like market size, which might have influenced the demand for innovation, the contrasting growth records of Britain and France are hard to square with endogenous growth models.[18] It is, of course, disconcerting for this theorythat in 1750, on the eve of the Industrial Revolution, Britain had just experienced half a century of virtual demographic stagnation. One might also point out that if population size is critical and that it is population growth that "liberates" Malthusian economies from their stagnation, China, where population grew from 130 million in 1650 to 420 million in 1850 yet where no Industrial Revolution could be discerned, should be of some concern. An interesting argument is made here by Justin Lin (1995), in a paper overlooked by many of the growth theorists. Lin argued, that the relationship between population size and technological change depends on the nature of the source of innovation. In a world in which new technology is based entirely on experience (that is, learning by doing), greater size would imply more innovation, assuming that the advances were disseminated effectively over the larger unit. Once progress begins to depend more on experimentation and theory, such advantages disappear. Lin maintained that the success of China

[17] It is indeed striking that prior to the rise of the British economy to the fore, Europe's most successful economies tended to be city states (Hicks, 1969, p. 42). City states, with high density but relatively overall small populations had an advantage in solving the problems of setting up effective institutions of commerce and finance. Market size was less of a problem in part because the fixed costs of setting these institutions up were not all that high, and because they tended to be open economies. The main source of economies of scale was not economic but military. Military power depended on total income and population.

[18] Some later models in the spirit of Kremer, such as Jones (2001), attempt to provide a solution to this problem by assuming increasing returns in the production of goods and by allowing the number of new ideas to be a function of the existing stock of ideas.

in the Song period as opposed to its relative stagnation in the seventeenth century and beyond were a function of the changing innovation process.

In any case, while the Kremer model can account for global growth rates prior to 1700, it strongly underpredicts growth thereafter. Perhaps more seriously, there is a problem of identification here: growth may have accelerated in some parts and periods as a result of factors unrelated to the hypothesized population-size-innovation mechanism. As more resources became available, demographic growth accelerated. The simple correlation of population size and growth rates is not a proof of the underlying endogenous growth model; indeed it could just as well be taken to be a confirmation of the Malthusian model. Modeling alternatives are needed if we want to account for the speed of growth after 1700, as well as for the variation between countries.

A second class of models in which size matters takes technological change to be exogenous, and models a set of conditions under which new techniques will be adopted. Early models in the tradition of Murphy, Shleifer and Vishny (1989) also relied on demand effects, and hence the size of economies, to explain when a "big push" might occur. In order to pay the fixed cost necessary for adopting modern production, demand needs to be sufficiently high. In typical "big push" models, this is only the case if a whole range of industries industrializes. The chances of this occurring increase with total output. One implication of these models is that industrialization may have been feasible long before it got underway – if only everybody had decided to invest earlier in fixed-cost technology, profits would have been high enough to justify the expense. Simple coordination failure can thus undermine the transition to modern technology. Possible modifications and extensions of this approach also assign a role to the income distribution and the structure of demand.

How realistic are these "big-push" models fo the transition to modern growth? Models in the "big push" tradition run into similar problems as population-based endogenous growth; the European experience after 1700 does not suggest that absolute size of economies is a good predictor of the timing of industrialization. Moreover, most of the technologies adopted during the Industrial Revolution required only limited up-front investment, and were often financed by retained earnings or informal credit networks. Before the late nineteenth century, fixed costs were typically small in manufacturing, and overhead investment in canals and turnpikes. When it comes to production technology with high fixed costs, adoption decisions *after* 1870 could possibly be explained by the big-push framework. Yet by that point in time, international trade was already doing much to break down the link between the size of the domestic economy and the possibility of technology adoption. If there were large fixed costs before 1870 they were in infrastructure, not in manufacturing. Yet these infrastructural investments — canals, turnpikes, harbors— do not appear to have suffered a great deal from capital scarcity, the Bubble Act notwithstanding, and were financed without too much difficulty by local notables(Michie, 2001).

Indivisibilities also play a crucial role for models that put risk diversification at the heart of adoption decisions. Acemoglu and Zilibotti (1997) argue that at low levels of development, the volatility of growth rates is high. [Joachim: the summary of the AZ model is a bit weak, can you firm this up??] Households need to diversify their investments. Productive projects require substantial setup costs. In order to invest in them, households need to rich enough – otherwise, they would end up putting "all of their eggs in one basket". Here, industrialization effectively depends on a number of lucky draws. It also has the feature that, since households do not take into account the effect of their investment decisions on aggregate productivity, industrialization may be delayed because of a co-ordination failure. The model is attractive in that it incorporates a stochastic component – industrialization may partly be the result of chance. Not every aspect of actual industrial transformations is fraught with meaning – and the country that actually went first could simply have been lucky. Yet the size of most industrialization projects was relatively small – even the largest textile mills, had they been financed by a single person, hardly represented a large risk concentration for modestly wealthy individuals. Much diversification, moreover, took place within the existing business structure of Britain during the Industrial Revolution.[19]

The debate to which extent size mattered is complicated by the fact that size has been argued to have mattered not only for technological change but also for more traditional sources of growth. The rise of population that took place without a collapse in per capita incomes may have generated positive externalities of a different kind. Regardless if size mattered to the generation or adoption of new technology, as the endogenous growth models suggest, the oldest and in some ways most elementary of mechanisms – a simple increase in the division of labor as a result of greater population size and density – could also have contributed to an acceleration in output growth. Kelly (1997) presents a model of "Smithian growth" where trade integration is furthered by improvements in transport infrastructure, leading to an acceleration of growth. He applies this model to Sung dynasty China. Similarly, in Europe, higher population densities and greater economies generated the scope for positive externalities, partly through improvements in turnpikes and canals (Bogart 2005a, 2005b).

In exogenous growth models technology just happens and adoption decisions no longer are modelled explicitly and size itself no longer affects technology or productivity change. In one example, Hansen and Prescott (2002) argue that technological change in both the land-using (diminishing returns) and the non-land-using mode of production was exogenously given and constant. They assume that over the course of each generation of 35 years duration, productivity increased by 3.2 percent in the "Malthus sector" (i.e. agriculture, where labor is subject to declining marginal returns) and by 52 percent in the "Solow sector" (where all factors of production are reproducible). Initially, only the Malthus technology is used. Eventually, as the productivity of the unused technology increases exponentially, the Solow technology becomes competitive and is adopted. In this setup, an Industrial Revolution is inevitable, and does not depend on anything other than the growth rates of productivity chosen for the calibration. It is also difficult to square with European economic history as a whole, as well as with the differences between countries. At the point in time when overall growth rates began to accelerate, both the land-using sector as well as the industrial sector became more productive – according to some measures, at relatively similar rates (Crafts 1985). By definition, the model has nothing to say about which country industrialized first, and why – the entire world is its unit of observation.[20]

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[19] In a recent important paper, Pearson and Richardson (2001) have shown that the typical entrepreneur in the Industrial Revolution was heavily diversified. Rather than describing the entrepreneur as a single-minded owner-manager who spent his entire life on the one business, they show the extent to which early entrepreneurs were involved in non-core ventures. Cotton masters and other textile producers in Manchester, Leeds, and Liverpool, for example, could be found as directors

[20] The only obvious alternative is to posit differential rates of productivity increase in the Solow sector, which would rather be a way of assuming the result.

c. Changes in demographic dynamics before 1830

One of the biggest challenges in interpreting the history of growth in Europe before 1850 comes is the rather sudden increase in population growth in Europe in the second half of the eighteenth century, after a period of stagnation in the first half. The latest revisions of the Wrigley-Schofield (1997) English population estimates reinforce the impression that fertility increases dominated as a cause of more rapid growth; mortality played a role, but it was responsible for only about one third of the acceleration.[21] Regardless of whether one accepts Wrigley and Schofield's interpretation of the Malthusian model, it seems that by 1750 the old demographic regime was breaking down.The work of Patrick Galloway (1988) shows that in the middle of the eighteenth century the short-term behavior of British vital rates was no longer very responsive to changes in prices. This suggests that, in contrast with the arguments of growth theorists, the Malthusian regime was falling apart *before* the Industrial Revolution and not as a response to it.[22] The unsolved question to date is why.

Regardless of what the sudden population spurt did, it leaves as yet unexplained how and why it happened. Models that link population dynamics to technological progress itself, such as Galor and Weil (2000), run into timing problems, namely that population growth started in the mid-eighteenth century, *before* any serious impact of technological change on output per capita can be discerned. It remains therefore unexplained itself. If there is any challenge left to economic theory in explaining big events in history, this development is a prime candidate. The challenge is compounded by three complicating factors. One is that even in Britain, the demographic transition started before the Industrial Revolution could have possibly have affected living standards. Second, the demographic revolution spread through many parts of Europe, regardless of their level of industrialization and the speed and nature of the industrialization process seem to have been unaffected by the decline in mortality. Third, the mechanism through which population increased seems to have differed from country to country, in some such as Britain increases in fertility and mortality accounting for about half the growth each, whereas elsewhere birth rates stayed constant or even declined from an early date, as they did in France and mortality decline accounts for almost all of the population growth. Unified models that link both birth and death rates in the economy are hard to construct, in part because they not only respond quite differently to economic and environmental shocks, but also because they affect one another in complex manners. Significant progress in this area has been made in two path-breaking papers by Sunde and Cervellati (2005, 2006).[23] It seems plausible to link declines in

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Wrigley (1983) showed that without mortality decline, 18C growth would have accelerated by 1.25 percent; without fertility change, growth would have improved by 0.5 percent. This implies that over 70 percent of the acceleration was driven by changes in fertility. Wrigley and Schofield (1997) qualify these conclusions to some extent, finding a faster decline in mortality, but the relative rankings are unlikely to change significantly.

22 It also suggests that separating institutional factors from the Malthusian model is a serious simplification, because the Poor Law played an important role in cushioning the impact of high food prices on demographic behavior (Post, 1990).

23 In Cervellati and Sunde (2005) the relationship between mortality and human capital investment is explicitly modelled. This is a little explored aspect of modernization, but one that was historically of some importance. All other things equal, longer life expectancy would encourage investment in human capital, although it is important to emphasize that a reduction in infant mortality would not directly bring this about, because decisions about human capital are made later in life. Increases in life

mortality to human capacity to fight disease through more educated people who led more hygienic lives, breastfed their children, and had access to medical care. Yet the historians will point out that mortality in this period was probably dominated by a single fortuitous event, the discovery of smallpox vaccination (e.g., Mercer, 1990), and most of the impact of education on mortality was offset by the urbanization than accompanied industrialization, leading in fact to heightened mortality rates (Huck, 1995).

d. **Institutions and the Industrial Revolution**

Much of the modern debate about growth centers on the relative importance of institutions versus human capital (Glaeser et al. 2004, Acemoglu and Johnson 2004). In cross-sections of countries from the late 20th century, constraints on the executive tend to be positively correlated with higher per capita output. Because of the potential for reverse causation— with higher income per capita improving institutional quality — work on modern data has principally focused on finding an exogenous factor that affect institutions, but not economic outcomes and so can be used to instrument for institutions. One such factor that has been used with great success is historical settler mortality. In a series of papers, Acemoglu, Johnson and Robinson (2001) show that countries in which white settlers had a high chance of survival ended up with more desirable institutional arrangements. They are also markedly richer, making it much more likely that the link between institutions and efficiency is causal. [Joachim: can you incorporate the critique by Ola Olsson and David Albouy and AJR's replies?] Despite some challenges to the quality of the data, the basic relationship appears to be robust. What is subject to vigorous debate is its meaning. By far the best research on the importance of institutions in European economic development has been carried out in the context of medieval and early modern Europe (Greif, 2005), and surprisingly no detailed work to date has been carried out to explain the British Industrial Revolution.

Three observations to summarize the importance of institutions in the post-1750 transformation of Europe are in order. One is that throughout Western Europe we observe after 1750 a rising tide against the rent-seeking institutions that are associated with the mercantilist *ancien régime* (Mokyr, 2006). The roots of this reaction involve some combination of the changing political influence of economic elites and the influence of a more liberal ideology. Second, these changes in most cases had to be imposed through political violence (in the United States and France). The only apparent exception is Britain, where the existence of a meta-institution (i.e., Parliament) could adapt to changing circumstances and beliefs and reform the system peacefully and without major upheavals. Yet even here it could be argued that the settlement following the Glorious Revolution would not have been possible without the bloodshed of the Civil War. Third, as we have seen earlier, the precise mechanisms through which "better" institutions affect economic growth are yet to be specified. The leading candidates are "law and order" and the efficient protection of property rights, the provision of public goods, acting as a coordinating and standard-setting agent, and the direct encouragement

expectancy at age 10 or so are more relevant here. A second relationship in this model is that life expectancy itself depends on the level of education of the previous generation: better educated parents will be better situated to help their children survive.

of the knowledge-producing sector.

The idea of law and order and the enforceability of contracts has played a major role in the accounts that link between institutions and economic growth. However, this tends to slight private-order institutions, in which contract enforcement depended more on voluntary compliance that depended on reputational mechanisms than on third-party enforcement of contracts. In a recent paper, Mokyr (2007) argues that in eighteenth century Britain such institutions played a major role in allowing markets to operate. The number of civil suits declined sharply in the eighteenth century, a surprising development that historians have found difficult to explain (Brooks, 1989). One hypothesis is that indeed Britain after1650 turned into a somewhat gentler and kinder society (Stone, 1985). It seems more likely, however, that within a larger class of people a stable equilibrium in which people were successfully signaling trustworthiness had emerged. The focal point of these equilibria was the belief that middle class people could adopt certain virtues associated with gentlemanly behavior; since gentlemen were supposedly indifferent to wealth and not greedy, they could be expected to cooperate in one shot p.d. games. Moreover, the enormous growth in formal and informal social networks in eighteenth century, through the growth of friendly societies, masonic lodges, and eating clubs. The effect of this growth was to make reputational mechanisms more effective, since non-cooperative behavior would soon become known. It can be argued that such informal institutions not only supported markets, but also helped Britain take the technological lead, because the success of its institutions made its apprenticeship system particularly effective (Humphries, 2003). As a consequences Britain could count on a large number of highly skilled craftsmen and mechanics, whose role in the Industrial Revolution was critical.

The political economy of Britain during the Industrial Revolution has become a topic of interest to economists (Acemoglu, Johnson and Robinson, 2005; Acemoglu and Robinson, 2006). The authors stress that political power matters in large part because it makes the redistribution of income possible. They distinguish between *de iure* power, that is, the power to pass formal laws and statutes, and *de facto* power, which includes the physical ability to overthrow the regime if those who have it do not find the policies to their taste. While by 1720 Parliament concentrated a great deal of *de iure* power and had thus elevated itself to the status of a meta-institution, it still needed to be concerned with the *de facto* power of the large masses of middle class people who accumulated increasing economic wealth and yet were to a great deal disenfranchised until the reforms of 1832 and 1867. This approach is refreshing in that it insists on incorporating political power into the story of economic development during the Industrial Revolution. It is worth pointing out, however, that their account to date excluded the growing influence of Enlightenment thought on political institutions, and that the full analysis of what *de facto* power consisted of is still incomplete. The physical power of the British military to suppress internal rebellion was demonstrated fully by the harsh suppression exercised during the 1790s when the fear of a Jacobin revolt was most acute and again during the Luddite riots. It may thus be that *de iure* and *de facto* power coincided to a great extent, and perhaps that was the key to the success of Britain's political model. It is striking, nonetheless, that while those who had political power did use it at times to redistribute income to themselves (most blatantly by the reformulation of the Corn Laws in 1815), the tendency to do so lessened as the first half of the nineteenth century wore on, and by 1860 rent-seeking in Britain was at a historical nadir.

One of the more interesting institutional aspects of the Industrial Revolution is the importance of IPR's in the early stages of technological progress. Jones (2001) is the only growth paper to date that models this important institutional parameter directly, and it turns out to play a pivotal role in his model in whether the Industrial Revolution was "inevitable."[24] Jones's parameter π_t, which is the proportion of total consumption allocated to people employed in the ideas-generating sector is computed to match the data, but displays a bizarre history (Jones, 2001, p. 24), actually falling from .44 percent to zero between the sixteenth and the eighteenth century, rising sharply in the eighteenth century, then falling to half that value in the nineteenth century, before leaping by a factor of 12 to 5 percent in the twentieth century. Yet nothing in his model allows for the complex motivation that propelled the ideas-sector in earlier history, in which many natural philosophers and inventors were as much interested in signaling as in financial gains, much like a modern open-source technology (Lerner and Tirole, 2004). It is also worth to note that a recent attempt to estimate the value of inventions accruing to the inventors for modern America has found that only about 2.2 percent of the value of an innovation is captured by the inventor him- or herself (Nordhaus, 2004). Whether the number was higher during the Industrial Revolution seems unlikely. The British patent system was far from user-friendly: it was costly to file a patent, and often hard to defend patents against infringers (Khan and Sokoloff, 1998; Dutton, 1984).The fact that Britain's system was thus less likely to encourage potential inventors than the corresponding U.S. system does not seem to have affected British technological leadership before 1850.

Modeling the production of "new ideas" is of course one of the hardest things to do in growth models, and endogenous growth models have had to simplify away much of this historical richness. Thus the literature has not dealt effectively with the high riskiness of the inventive process, in which investing in the "ideas-producing" sector is more akin to purchasing a lottery ticket than to choosing an occupation.[25] Perhaps more interesting is the failure of these models to recognize the different ways of assigning property rights in the two separate segments of the "ideas-sector." Whereas prescriptive knowledge, that is, techniques, could be patented and thus be allocated some form of property-rights, this was never done with propositional knowledge in which priority credit assigned to the owner did not include exclusionary rights. Yet it is hard to understand the growth of technology during the Industrial Revolution and after without explicitly recognizing the feedback between these two forms of knowledge (Mokyr, 2002; see also David and Dasgupta, 1994). Finally, it would be a mistake to identify IPR's during the Industrial Revolution with the patent system as such. The operation of the patent system awarded monopolies to inventors, yet infringements and other failures of the system implied that first-mover advantages and old-fashioned government and private-sector prizes were as important as the rents earned by inventors.[26]

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[24] This parameter π in Jones's model defines the proportion of total income that accrues to those who are employed in the "ideas-sector" and in equilibrium equals the fraction of labor in the economy allocated to producing new ideas.

[25] Indeed, this aspect of technological progress may well be better analyzed by behavioral economists and decision theorists who deal with models in which people systematically overestimate their own chances at succeeding. This was already understood by Adam Smith who noted "Their absurd presumption of their own good fortune is ... still more universal [than people's overestimating their own abilities]... the chance of gain is by every man more or less over-valued, and the chance of loss...undervalued" (Smith [1776], 1996, p. 120.

[26] The literature on the operation of the patent system in Britain is quite large, for an introduction see Dutton (1984) and MacLeod (1988).

e. Human and physical capital in the Industrial Revolution: theory and evidence

The most influential class of formal models created in the past decade sees the Industrial Revolution as largely synonymous with the demographic transition and an increasing role for human capital. Becker, Murphy and Tamura model an economy without a fixed factor of production. Improvements in human capital in turn directly feed into higher output. Human capital is produced, it is assumed, by investments of parental time. Parents maximize their own utility, derived by their own consumption, the number of children they have, and their quality. When parents start to invest massively in the education of their offspring, growth rates rise. Once incomes are high enough, fertility falls, leading to yet more investment in child quality. In this model, human capital and growth are basically identical. Lucas (2002) extends the Becker et al. approach by adding a land-using sector with diminishing returns, and a modern sector where human capital enters linearly. In the Malthusian trap, there is no investment in human capital. One of the main strengths of the "unified theory" of Galor and Weil is that their model actually predicts that in the first stages of the Industrial Revolution the role of human capital is modest, because the rate of technological progress initially is driven by size, not by quality (Galor, 2005). Yet, while it is consistent with the facts, it is not the only model and tale that can be told that predicts this.

Once the Industrial Revolution has taken place, there is ample investment in human capital; growth surges, and fertility rates decline because investment in human capital is costly. These models offer no good explanation for how the switch from one regime to the other might happen. They do depend on the twin assumptions that investment in human capital through the rearing of "higher-quality" (i.e., better-educated) children is an input into the process of technological change, and that the rearing of better-quality children in the end affects fertility behavior.

The first assumption is not an obvious truism. While the technology of the Industrial Revolution was surely not the single creation of a few mechanical giants in the hagiographic traditions of Victorian writers such as Samuel Smiles, but neither was it a popular mass-movement. It was brought about by a technological elite of inventors, engineers, mechanics and skilled craftsmen, whose dexterity and ingenuity was critical. Not only new ideas, but also the ability to implement them, turn blueprints into functioning designs and maintain and operate them effectively were central. Yet none of those involved more than a minority of the labor force. For the rest of the population, as we shall see below, the links between human capital, skills, and growth are thus far a matter more of convenient modeling and speculation than of historical fact. For the period before 1850, there is little evidence to support human-capital based approaches and an increase in the rate of return on human capital due to the acceleration of technological progress. Skill premia were flat or declining (Clark 2003). The models by Lucas and by Becker et al. seem geared towards the developments after 1850, when fertility began to decline in earnest in some European countries. They have little to say about developments before the middle of the eighteenth century, despite the fact that some European economies already cast off Malthusian patterns of fertility behavior.

At least some of the assumptions of the model emphasizing the quality-quantity trade-off and the rather abrupt transition to quality need to be reevaluated in view of the historical evidence. Accounts of the quality-quantity trade-off need to be anchored more firmly in evidence from family history. One doubt that arises is to what extent investment in quality before 1800, too, was intensive in parent-time. What role did grandparents, siblings, and hired help have in producing child quality? To what extent did parent time in rearing children come at the expense of income and to what extent did it either replace or constitute leisure consumption? How much joint-production and multi-tasking in child rearing was feasible? The main form that training took was apprenticeship, in which a contract been the trainee and the master involved an indenture, a commitment by the trainee to work during his learning period, and at times cash payments by parents (Humphries, 2003). Secondly, there is no doubt that some forms of human capital (such as literacy and numeracy) were on the rise long before the Industrial Revolution. In part this was due to the Reformation, in part due to slowly rising incomes (children's quality was a normal good), and possibly to a rising demand for literacy in the service sector during an age in which commerce and finance were growing rapidly. To complicate matters, during the Industrial Revolution itself, literacy rates were probably largely stagnant; there is little evidence of an increase in the returns to education before 1850 (Schofield 1973, Clark 2003). Measuring literacy rates in a consistent and comparable fashion is no minor matter, especially with the kind of pre-1800 sources available for this matter. Baten and van Zanden recently examined book production in early modern Europe. They find a veritable explosion of output per capita after the invention of moveable type, with production increasing between tenfold and a hundredfold. The Netherlands and the UK are far ahead of other countries – the richest areas consumed the largest number of books.[27] A recent literature survey, focusing on the ability to sign one's name in around 1800, rates this proportion at about 60 percent for British males and 40 percent for females, more or less at a par with Belgium, slightly better than France but worse than the Netherlands and Germany (Reis, 2005, p. 202). However, Britain was considerably richer than those countries (Netherlands excepted), and if we allow for the fact that literacy was in part a desirable good that people consumed more of when they became richer, Britain's lack of advantage in literacy is all the more striking (Mitch, 1992, 1999). Its ability or willingness to educate its young did not appreciably improve during the years of the Industrial Revolution. School enrollment rates did not increase much before the 1870s (Flora et al 1993).

The main conclusion has to be that, while human-capital based approaches hold some attractions for the period after 1850, few growth models have much to say about the first escape from the negative-feedback low growth regime that survives contact with the most basic facts in economic history. Exogenous growth models, where they emphasize institutional constraints, hold greater promise, even if the messy detail of historical reality is proving hard to press into the Procrustian structure of some modeling approaches.

f. Factories and the re-organization of production

At the microeconomic level, the Industrial Revolution's main impact was to establish the Factory System, in which workers were physically separated from their homes and did their work in designated spaces and circumscribed times. Many scholars, including Karl Marx, Max Weber

[27] The authors argue that their indicator of human capital accumulation is a good predictor of subsequent growth. Baten and Van Zanden 2006.

and Paul Mantoux, regarded this change as the fundamental transformation of the Industrial Revolution rather than the beginnings of economic growth.

Economic models explaining the rise of the Factory System have fallen into three basic categories. The most obvious focuses on physical economies of scale, which simply made production at the household level uncompetitive. While undeniably important, this approach falls short of explaining the entire phenomenon, since some factories arose using more or less the same techniques used in households and quite a lot of machinery was originally designed to be used in domestic industries (Berg, 1994). A second approach emphasizes asymmetric information and transactions costs in production, emphasizing the importance of monitoring inputs rather than output (Williamson, 1980; Szostak, 1989; Langlois, 1999). This need arises in a variety of circumstances, all of which became more pronounced during the Industrial Revolution. One is the growing importance of product quality, and in particular the need to conform to standards in a more integrated market setting. Another is need to maintain and properly use costly equipment and intermediate inputs. In a high-powered incentive structure, where workers were paid in direct proportion to output, there was an incentive for workers to skimp on quality. If quality was costly to observe, it made more sense to supervise and control the labor process directly. Finally, a finer and more integrated division of labor implied that individual effort was harder to observe than group effort, and this meant that such processes had to be moved to centralized locations and workers paid time- rather than piece rates. Once time rates become inevitable, it becomes all but impossible to allow workers to work at their homes.

Clark (1994) argued that the strict discipline of the factory offered a way to overcome workers' own inertia – to pre-commitment to working hard and long when they would otherwise be tempted to take time off. Even if this factor explained the workers' willingness to submit to factory discipline, it is not clear if it helps us to explain why the factory system arose when it did. Mokyr (2001) offers a different approach: as the technology underlying industrial production became more sophisticated and complex, the amount of knowledge necessary for efficient production exceeded what a single household could muster. Hence a division of knowledge and expertization became inevitable, but since communications were still largely personal, it became inevitable to concentrate different specialists on the same premises.

In a recent important contribution, Geraghty (2007) tries to assess the importance of various factors supposedly contributing to the rise of the Factory System. He distills the three reasons for factories down to three basic factors: investment in machinery and costly equipment; adoption of organizational innovations (such as shop floor rules and incentive-compatible compensation schemes); and a growing emphasis on output quality control. Rather that regarding these three elements as additive, he shows that they were complementarity in a strong sense, in that firms that engaged in one of these activities would experience a higher payoff of one of the others. This complementarity derived from many sources, such as the embodiment of new technology in capital goods, and the inability of firms to produce the highest-quality goods without using the best techniques. The high cost of this equipment then necessitated supervision and balanced incentives. Supervision was also strongly complementary with product quality, which seems intuitively obvious. Geraghty has collected data for a large number of British firms and shows that empirically there are strong pairwise complementary relations between factory organization and machinery and factory organization and quality control. The nature of the profit-maximizing decision had become more complex, and employers needed to simultaneously determine the choice of technique, the level of worker effort, and the way incentives were set up and communications and decisions flowed through the firm hierarchy.

g. **Was an Industrial Revolution Inevitable?**

Growth before 1850 was, more often than not, a fleeting phenomenon. There were many "false starts" and stops - periods of rapid growth followed by stagnation and decline (Braudel 1973; Goldstone, 2001). It is at least doubtful that there was much about Britain in 1700 that guaranteed that the next episode of rapid growth would not end like earlier ones. Both economic historians and growth theorists are ambiguous about the inevitability of the Industrial Revolution and the role of chance. One group emphasizes the role of historical accident both in terms of timing and location. Crafts (1977) argued that accidental factors, and not systematic advantages, were crucial -- that France, for example, could have easily industrialized first had it not been for a number of random factors. Acemoglu and Zilibotti (1997) build a probabilistic model of the Industrial Revolution where technology adoption depends on the realization of shocks. Lucas (1998) adds a sudden, one-off increase in returns to human capital to his model to produce an Industrial Revolution, which could be interpreted as reflecting another historical accident. Historians find it difficult to agree on whether the "rise of the West" was a contingent event that could have turned out very different if initial circumstances had been slightly different (Tetlock et al., 2006).

In contrast, both economic historians and growth theorists have seen little role for historical accident. In models such as those by Galor-Weil (1998) and Hansen-Prescott (2002), given a certain set of starting values, an Industrial Revolution is inevitable. The very idea of a unified growth model implies such inevitability, since a single model describes how the system evolves over time and makes the transitions. It would, of course, be possible, to amend the Galor-Weil and Galor-Moav models to reproduce a history in which society is stuck forever in a Malthusian poverty trap, but that would defeat their very purpose. The dynamics governing growth from the earliest date ensure that there has to be an eventual acceleration. In Charles Jones's paper (2001), the Industrial Revolution is not inevitable and depends on certain parametrizations of the model.[28]

While many economic historians will be skeptical about the idea of "inevitability" 7because of its "hindsight bias" (the bias that make people feel that whatever happened had higher ex ante probabilities than it actually had), there is a school of thought that has defended such an approach. David Landes, (1994), responding to Crafts's argument that Britain's role as the First Industrial Nation may have arisen by chance, has argued that big events need big causes. In his view, both the Industrial Revolution and Britain's role in it were determined by that country's starting conditions. Yet there is no contradiction between the argument that big events need big causes and that the Industrial Revolution was not pre-ordained from the start. Some accidents, such as the destruction of the Spanish Armada in 1588, may have been fairly "big." At some critical junctures of history, a point of bifurcation may have occurred, and that accidental factors may have steered economies on one path or another; once on that path, their direction was clearly no longer accidental.

[28] Specifically, as Jones (2001, pp. 31-32) suggests, what made the Industrial Revolution possible was the sudden increase in the "production" of ideas that, in his model, depends on a sharp increase in the remuneration of the sector that produces ideas.

As noted earlier, of all the possible historical paths, we only observe one. It is easy enough to imagine that it could have looked different, but how different? What appears to underpin theorists and historians' interest in the role of accident are the wide differences in the fate of individual countries, and the many promising starts that never led to a "take-off" into self-sustaining growth – more often than not, before the transistion "from Malthus to Solow" occurred, there were many episodes of a long and stony path "from Malthus to Malthus." If progress is to be made, theorists should aim to offer models that have something to say about the factors that influenced adoption probabilities for new technologies in the past, and they ought to assign an explicit role to chance; ideally, they should also offer quantitative answers to question how much the individual features of a country influenced industrialization probabilities.

4. Growth and the emergence of the "new economy"

Models in the Lucas, Becker, and Galor et al. tradition offer a unified and consistent account of the transition into self-sustaining, rapid growth of per capita incomes. They are ultimately driven by human capital accumulation. More rapid technological change (either exogenously given, or as a result of larger population size) increases the *returns* to human capital. Parents respond by producing higher-quality offspring. Additional human capital input in the economy boosts growth and accelerates technological change yet further. Because parents respond to the changes in the quantity-quality-tradeoff, fertility declines. Hence growth becomes intensive rather than extensive, boosting incomes and not population size. In this section, we examine each of these facets in turn – the importance of human capital for growth in the emergence of the 19th century's "new economy", and the importance of quantity-quality tradeoffs for fertility change. We then discuss what determined the accumulation of useful knowledge.

a. Education and the first "new economy"

One factor that is common to models in the Lucas tradition is that they predict an increase in the demand for human capital during the transition to self-sustaining growth – and that technological change should be heavily skill-biased. This is historically problematic. There seems to be little correlation between widespread literacy and schooling and the onset of technological progress. Mitch's (1998) view has been that, if anything, nineteenth century Britain was overeducated. By this he means that the amount of human capital exceeded that which was needed by the demand for production. Reading and writing were desirable in their own right, that is, as consumption goods, and were not just parts of an investment process in which the rate of return on the margin would equal to interest rate. It is far from clear that the main developments in manufacturing during the Industrial Revolution, or even developments in its aftermath, depended heavily on an increase in human capital, as conventionally measured. Possibly, some administrative tasks became more important, and the rise in pay rates for highly literate workers observed by Boot (1999) suggests that there were some (small) parts of the economy where formal education may have paid off. Yet technological change itself was probably not skill-biased in the normal sense of using large quantities of literate workers with many years of formal schooling. Research on the output of textile workers in New England showed that only experience was a good predictor of output; the ability to read or write was neither useful in its own right, nor did it go hand-in-hand with other, unobserved characteristics that would have raised output (Leunig 2001).

Many contemporaries commented on the de-skilling that accompanied the Industrial Revolution.[29] In the textile industry, the cotton mules, spinning jennies and Arkwright frames replaced skilled labor with a mixture of capital and unskilled labor. In some cases, innovation deliberately sought to replace the skilled "labor aristocracy" whose bargaining power the cotton masters resented (especially in the case of mule-spinners). High wages of skilled mule spinners outside Britain apparently acted as a strong incentive to adopt ring spinning, which could be performed by unskilled labor (Leunig 2003). In Britain itself, and despite some inherent technical limitations, highly skilled mule spinners were cheap enough to make the industry competitive all the way up to 1914. All this suggests that neither formal-education based indicators of skills nor the nature of technological change offer decisive support to the predictions of unified growth theory. However, the current state of knowledge on skill-bias of 19th century technological change is far from complete. Perhaps if one could construct input-output tables with human capital as a separate input, when linked with more data on the schooling and skills of the workforce, these could help to shed more light on many of the crucial issues. Such a project, conducted for a number of European countries and the US in the 19th century, could help scholars construct more detailed estimates of the embodied skill content of production and the extent to which this changed over time.

One indicator of the changing role of skills is the skill premium. Unfortunately, our knowledge of the behavior of the skill premium over time is very incomplete, because estimates are based on a few skilled occupations, which may not be representative. Moreover, the skill premium is a reduced form measure, and changes in it could reflect any combination of changing supply and/or demand factors. Williamson (1985) claimed to show that the skill premium surged until 1850 in Britain, and declined thereafter. The consensus view amongst economic historians does not accept the Williamson interpretation. As Feinstein (1988) convincingly demonstrated, there is no clear evidence that skill premia changed at all over time. This is problematic for authors such as Doepke and Zilibotti (2005), who argue that child labor laws were introduced in England after wage inequality surged. In their model, the political equilibrium that sustains restrictions on child labor require a substantial premium for well-educated members of the workforce. In this way, there is an institutional response to the voracious demand for human capital. Unfortunately, Doepke and Zilibotti reliance on Williamson's flawed data undermines the credibility of their results. Galor offers an explanation why skill premia failed to rise in 19th century Britain. He argues that, after the introduction of compulsory schooling, supply was so ample that premia remained flat.[30] This would offer a plausible interpretation if skill premia had increased *prior* to the introduction of the Factory Acts. Yet this is exactly the key piece of the puzzle that is missing. Moreover, much of this literature ignores the fact that in the nineteenth century "skills" were not yet, as a rule, acquired at schools, but transmitted through personal contracts.

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[29] Adam Ferguson, Adam Smith's contemporary noted in 1767 that "Many mechanical arts require no capacity ... ignorance is the mother of industry as well as superstition... Manufactures, accordingly, prosper most where the mind is least consulted."

[30] Galor 2006, private communication.

Most of the skills that the workers' elite of skilled craftsmen brought to the factories were the culmination of a century-long accumulation of expertise in traditional crafts. If the rise of new technology, and the high complementarity of their skills with the adoption of more productive machinery, made their human capital more valuable, we should find changes in the wage premium for this group. One conceptually appealing test of human-capital based models of the Industrial Revolution would focus on movements in the pay rate of this labor aristocracy, compared to the rest, and on the supply response that these differences in pay engendered. The failure of traditionally measured skill premia to show a rise may well mask an increasing polarization within the workforce, with industrialization raising the returns to supervisory and advanced mechanical skills, and reducing those for standard ones (such as blacksmithing, carpentry, and weaving).

If there is one area that shows promise for future work, it is the acquisition of factory- and task-specific skills. Steep experience-based earnings profiles in the textile industry apparently made acquiring skills attractive. During their early years, when unskilled workers such as brickmakers were better paid, skilled workers were effectively investing their own human capital of a highly specific kind; by age 35, they could look forward to earning 2.3 times the wages of a brickmaker, and still more than a coal miner (Boot 1995).[31] However, the total number of workers investing in their own skills was sufficient to keep overall premia for, say, skilled mule spinners, relatively low in England at the end of the 19th century (Leunig 2003). One valid test of the human-capital approach would focus on highly skilled workers such as the textile operatives examined by Boot and Leunig, and to ask whether they did receive greater rewards for investing in their skills (by accepting years of poorly paid on-the-job training) than, say, apprentices in traditional sectors?

For the time being, the jury appears to be out on whether increased human capital formation from the middle of the nineteenth century onwards was an endogenous response to changes in factor prices and other economic incentives, whether it was a result of higher real incomes (education for one's children being a normal consumption good), or whether if it reflects "exogenous" shifts in the supply of education, such as the long-delayed effect of the enlightenment, of nineteenth-century nationalism and nation-building, or attempts to increase social control over the lower classes.[32] Galor and Moav (2006) argue ingeniously that human capital was highly complementary with physical capital, and that therefore capitalists had an incentive to support and subsidize education. Since compulsory schooling played a crucial role in raising human capital, examining the history of their introduction becomes crucial. Galor and Moav offer a first step in this direction. They analyze voting records in the House of Commons, and argue that the educational reforms that came into force as a result of the Balfour Act of 1902 largely reflected the interests of capitalists in improving workers' education.

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[31] Coal miners are arguably a better standard of comparison, since the wage of textile operatives will also reflect differences in the harshness of working conditions – and since those in coal mines were probably worse than in textile factories, skill accumulation is a good explanation.

[32] The latter effect would be in the spirit of Acemoglu and Robinson's (2001) paper, which sees the extension of the franchise as a reaction to revolutionary threats. A similar argument could possibly be made about the introduction of compulsory schooling.

b. The human capital that mattered: Factory discipline, supervision, and the skills for microinventions

The idea that education and physical capital were strongly complementary is a powerful one, and as Galor and Moav indicates, provides a cogent alternative to the Marxian view of inevitable conflict between capital and labor. But what, exactly, was it that education did for the capitalists? The rise of the factory system required plenty of general skills that were not necessarily transmitted through formal schooling – discipline, punctuality, and respect, in addition to literacy and numeracy. The equipment and materials used by workers belonged to the capitalist and were costly. Factory owners needed to install into workers a culture of loyalty, and sobriety, a willingness to take instructions from and cooperate with other workers. This is a direct result of the expensive equipment in factories.[33] Beyond that, the more complex technology and finer division of labor created interdependencies between workers that required coordination between them that would have been hard to enforce unless workers were willing and cooperative. Wage premia for *disciplined* work in the factories were high vis-a-vis other, more self-determined forms of employment, and the factory system's profitability relied crucially on work intensity (Pollard, 1965; Clark 1994).

For similar reasons, monitoring workers was a highly important task. If "discipline capital" mattered more for the first Industrial Revolution than education, conventionally measured, economic historians should compile more comprehensive wage measures that capture the rewards for workers who successfully internalized the demands of the machine age. Also, if the returns to disciplining workers were large, we should find high and rising pay premia for outstanding foremen and other members of the evolving hierarchies that ensured the smooth running of 19th century factories. The most obvious testable implication of this idea that early factory owners should have a preference for the employment of comparatively more pliable workers, even if they were of low skill — i.e., women and children. This was very much the case in the early stages of the textile mills.

The technical skills of the few were complementary with the social conditioning of the many. In an important sense, the Industrial Revolution was carried not by the skills of the average or modal worker, but by the ingenuity and technical ability of a minority. We should recognize, however, that the new technology was generated by a small army of highly skilled men. These were the craftsmen, highly skilled clock- and instrument makers, woodworkers, toymakers, glasscutters, and similar specialists, who could accurately produce the parts, using the correct dimensions and materials, who could read blueprints and compute velocities, understood tolerance, resistance, friction, and the interdependence of mechanical parts. These anonymous but capable workers were an essential complement to the inventors and engineers, since they were the ones that turned models and designs into working machinery, maintained and operated it, and produced a cumulative torrent of small, incremental, but cumulatively indispensable micro inventions, without which Britain would not have become the "workshop of the world." They

[33] This insight is hardly indebted to modern theory: Karl Marx, in a famous passage, cites an industrialist telling the economist Nass au Senior that "if a labourer lays down his spade, he renders useless, for that period, a capital worth 18 pence. When one of our people leaves the mill, he renders useless a capital that has cost £100,000" Marx (1967, Vol. I, pp. 405–06).

comprised perhaps five percent of the labor force. This would put their counts in the tens of thousands but not in the millions.

c. The quality-quantity tradeoff and the demographic transition

Human-capital based models of long-run growth assign a crucial role to the fertility transition. It is normally modelled as a response to changing economic incentives. The predictions are that (i) skill premia surged, (ii) parents responded to this change in the trade-off between child quantity and quality by limiting fertility. As we saw, the first part of this argument is problematic – returns to human capital, conventionally measured, probably did not increase significantly before 1870. The second one will probably also have to be modified. Since the economic *benefits* of formal education were probably minor for working class employment, any model of parental fertility choice based on quality-quantity tradeoffs faces problems. What is more plausible is to argue that the net *costs* of child quantity increased in the second half of the nineteenth century as a result of compulsory schooling laws and child-labor prohibitions. Doepke (2004) argues that other government policies (such as education subsidies) could not have had a similarly large influence. Yet we do not know that government intervention was crucial in moving children out of the factories and into the classrooms. For the US, there is some evidence that state schooling laws had little influence on child labor (Moehling 1999). In the UK, Kirby (1999) argued that child labor laws came in at the same time when technological changes made the use of children in mining much less useful, and that there was not much of a causal role for government legislation in reducing employment rates.

If the importance of government intervention suggested by Doepke (2004) and Doepke and Zilibotti (2005) is confirmed, examining the economic and other factors behind the adoption of child labor laws becomes crucial. What also need strengthening is the evidence that higher net costs of child rearing (principally through lower employment opportunities) were important in reducing fertility. There are no cohort-specific studies of fertility behavior at the micro level that would unambiguously identify the impact of discontinuous changes in schooling laws and the like. Wrigley and Schofield's famous *Population History of England* is based on family reconstitutions that focus on rural parishes, and their data end in 1837. We have little information on what determined completed fertility rates, educational investment, age at marriage and the like in the industrializing cities of the North. More detailed demographic analysis of the fertility choices of the working class – combined with information on rates of school attendance etc. prior to and after the introduction of the compulsory schooling laws – could do much to further our understanding of how robust the empirical foundations of human-capital led interpretations of the Industrial Revolution are.

The history of fertility decline represents a further challenge to unified growth theory, and to much of economic demography. Little if any of the demographic changes predicted by standard models such as in Becker and Barro (1987) and Lucas (2002) are in line with historical facts. [Joachim: could you just make this last statement a bit more specific? *What* predictions?] Most of the fertility decline was concentrated in a few decades, starting in 1870 and accelerating after 1890. In general – with important exceptions such as in the case of France – mortality declines preceded the fall in fertility by decades (Lee 2003, Coale and Watkins 1986). In some countries, such as the UK, Germany, Sweden, the Netherlands, Finland, and Belgium, there were sustained and sometimes marked increases in fertility before decline set in. For example, the average number of children per woman rose from 4.5 to 5.5 in the Netherlands between 1850 and 1880. By 1900, it had returned to its earlier level. In most European countries, the first significant reductions in fertility occurred after the 1880s, long after industrial change had started to take hold on the continent. Some countries saw large declines in infant mortality before fertility started to decline (Sweden, Belgium, Denmark); in others, both series show a concurrent downward movement (France, Germany, Netherlands).[34] Differences in levels are equally puzzling: Swiss, Belgian and Swedish birth rates around 1850 were on the order of 30 per 1000, whereas in the Netherlands, Austria and Germany these were around 35 per thousand.

Finding an economic reason for the fertility decline has not been easy, and there is currently no consensus on the principal contributing factors (Alter 1992). The biggest project on the fertility transition, the Princeton European Fertility Project (EFL), concluded that there was no clear link between socio-economic factors and fertility change. Instead, ethnic, religious, linguistic and cultural factors appeared to be dominant (Coale and Watson 1986). The economic value of children, as far as it can be determined, did not change in such a way as to help in explaining the decline in fertility rates (Knodel and van deWalle 1986). The leading explanation for fertility change is the "diffusion model", where knowledge about prophylactic techniques spread along linguistic lines. The principal reason why scholars have accepted the findings of the EFL is the remarkable similarity in the timing of the transition.[35]

Studies that go beyond the broad aggregates and look at regional data from, for example, a single European state such as Bavaria, have sometimes reached different conclusions (Brown and Guinnane 2002), assigning a greater role to the opportunity cost of women's time, while at the same time also documenting the effect of other factors such as religion and political affiliation. The statistical basis for some of the EFP's conclusions may be less robust than had previously been assumed.[36] Independent of whether new, more disaggregated studies can find a role for economic factors in fertility change, the very simultaneity of the drop in reproduction rates across Europe in the decades before 1914 makes it unlikely that economic factors can ever be assigned a dominant role. Exogenous, non-economic factors probably dominated in the great decline of European fertility. This need not present a challenge to all growth models. Yet for the more ambitious class of structural models in the unified growth tradition, the apparent incapability of economic factors to have a clear bearing on fertility outcomes represents a challenge.

d. What sustained growth: science, technology, and "useful knowledge"

One organizing concept that has proven hard to model formally but without which no historically accurate picture of modern growth can be formed is the connection between science

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[34] Chesnais 1992.

[35] As Cleland and Wilson (1987) argue: "...the simultaneity and speed of the European transition makes it highly doubtful that any economic force could be found which was powerful enough to offer a reasonable explanation".

[36] A much larger research project on German fertility decline is now under way (Ogilvie et al. 2005), using that country's extraordinarily rich data sources.

and technology in the Industrial Revolution and beyond. Historical scholarship has bifurcated here into a minority view, which continue to view science and scientific culture as crucial to the Industrial Revolution (Musson and Robinson, 1969; Jacob, 1997) and a majority, which has dismissed the role of science as epiphenomenal and marginal (Mathias, 1979; Hall, 1974; Gillispie, 1980). Examples of the importance of science and mathematics to some of the inventions of the Industrial Revolution can certainly be amassed. It is equally true, however, that many of most the prominent breakthroughs in manufacturing, especially in the mechanical processing of textiles were not based on much more science than Archimedes knew, and that in other areas of progress, such as steam power and animal breeding, progress occurred on the basis of trial and error, not a deep understanding of the underlying physical and biological processes.

The debate between those who feel that science played a pivotal role in the Industrial Revolution and those who do not is more than a hackneyed dispute between a glass that is half full or half empty, because the glass started from almost empty and slowly filled in the century and half after 1750. Scientists and science (not quite the same thing) had a few spectacular successes in developing new production techniques, above all the chlorine bleaching technique, and the inventions made by such natural philosophers as Franklin, Priestley, Davy, and Rumford. While the Industrial Revolution in its classical form might well have occurred, with a few exceptions, without much progress in science, it is hard to argue that it would have transformed into a continent-wide process of growth without a growing body of useful knowledge on which inventors and technicians could draw. It is not possible to "date" the time at which this kind of collaboration began. In some areas it can already been discerned in the mid eighteenth century. It is equally clear, however, that in the crucial "new" areas of technology in the post 1820 years, scientific knowledge became increasingly important to the development of new technology. Two of the most remarkable developments of the era, the telegraph and the growing understanding of fatty acids in chemicals take place in the final decades of the classical Industrial Revolution. Trial and error, serendipity, and sheer intuition never quite disappeared from the scene, but the ability to know more about how and why a technique works makes it far easier to refine and debug a new technique quickly, adapt it to other uses, and come up with variations and recombinations that would not have occurred otherwise. In chemicals, steel, electricity, food processing, power engineering, agriculture, and shipbuilding technology, to name but a few, the ties between formally educated who tried to understand the natural phenomena and regularities they observed and the people whose livelihood depended (Mokyr, 2002).

The underlying institutions that made this growing collaboration possible have been investigated at great length. Although IPR's sure were of some importance, they cannot possibly explain the entire process, as we have seen. Instead a deeper and more encompassing social phenomenon was at play here, namely a growing interaction flows of information and interaction between people who made things (entrepreneurs and engineers) and people who knew things (natural philosophers). Not only that this interaction meant that the best that useful knowledge had to offer was accessible to those who could make best use of it, it also meant that the agenda of science was increasingly biased toward the practical needs of the economy. The bridges between *savants* and *fabricants* took many forms, from written technical manuals and treatises, to academies and scientific societies, where they rubbed shoulders and exchanged ideas. By the closing decades of the eighteenth century it was normal for scientists to consult to manufacturers looking for improved bleaches or more efficient engines.

By 1815, the need for this kind of collaboration had become a consensus, and the European economies competed with one another in encouraging them. In Britain, the Society of Arts, established in 1764, the Royal Institution, founded in 1799, and the Mechanics Institutes (first established by George Birkbeck in 1804) were examples of how private initiatives could carry out this task in the land where people believed above all in private initiatives. Less formal institutions abounded, the most famous of all being the Birmingham Lunar Society, which brought together the top scientists with some of kits most prominent entrepreneurs and engineers. Less well known but equally significant were the Spitalfields Mathematical Society, founded in 1717, and the London Chapter Coffee House, the favorite of the fellows of the Royal Society in the 1780s, where learned men discussed at great length the mundane issues of steam and chemistry(Levere and Turner, 2002). In France, Germany, and the Low Countries, government took a more active role in bringing this about (e.g., Lenoir, 1998). Not all of those efforts were unqualified successes: the engineers of the Paris *École Polytechnique* were often too abstract and formal in their research to yield immediate results. In Germany, the University system was on the whole rather conservative and resisted the practical applications that governments expected of them. New and more effective institutions were established, however, and the old ones eventually reformed.[37] The decades after 1815, then, were the ultimate triumph of the Baconian vision, that formed the basis for the founding of the Royal Society in 1660. The hopes and aspirations of Baconians like Samuel Hartlib, Thomas Sprat and Robert Hooke were slowly becoming reality. To achieve this triumph, Europe had to undergo changes in its institutional set-up of the accumulation and dissemination of useful knowledge, yet these institutions were based on the scaffolds (to use North's term) of an Enlightenment ideology that firmly believed in material progress and advocated concrete programs as to how to bring it about.

e. Capital and the rise of new forms of business organization

Growth in the 19th century relied heavily on capital investment. Savings as a share of national income increased in the UK after 1750. They had to – to equip the ever larger cohorts entering the workforce with machines and buildings, with a roof over their heads and shovels in their hands, savings had to increase. More importantly, at least at first, were the needs for circulating capital needed to purchase intermediate goods and hire labor. Eventually, as population growth rates declined, these high savings rates started to increase capital available per member of the workforce. Much of the post 1850 growth was driven by capital deepening. Calculated as a simple residual, not much tended to be left for the role of TFP.[38] That is why Abramovitz and David (1973), in their review of US economic history during the 19th and 20th centuries, spoke of the "rise of TFP" over the period. Joachim: I am lost here. Can you rewrite or drop this?

There is substantial agreement that the standard assumptions about the separability of capital

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[37]In Germany, universities had increasingly to compete with the technical colleges or *Technische Hochschule*, the first of which was set up in Karlsruhe in 1825. In France new *grandes écoles* were set up to provide more practical education such as the *arts et métiers* in 1804,

[38]Abramovitz and David 1973; Feinstein 1978.

and technological change are too facile. One way to go beyond the standard Cobb-Douglas function in growth accounting was explored by Crafts (2004), who examined the change in the relative cost of capital that made adoption easier. In the standard TFP framework, we would attribute the economic effect of this demand response entirely to "more capital", which to some extent will be "better and cheaper capital". The element that Crafts captures is that "more capital" only became affordable because of technological change. The method, pioneered by Oliner and Sichel (2000), simply adds the capital deepening in the new "revolutionizing" sector to the TFP estimate, thus deriving the total contribution of technological change. In many subperiods, the results are dramatic. For 1830-60, for example, adding capital deepening in railways implies that the role of technological change was eight times larger than previously calculated. It should be noted that there is now an upward- instead of downward-bias in the TFP calculations, since the underlying assumption is that without technological change, there would have been no investment in transport whatsoever – which is unlikely to be true, imperfect as early models were. Long after the railroad were introduced, horses remained the staple source of transportation power.

Allen (2005) goes beyond the Cobb-Douglas production function altogether, and uses a translog production function for industrializing Britain instead. He calibrates a model for the UK in the eighteenth century, and finds it to have very low elasticities of substitution in factor inputs; the production function is almost Leontief. The implication then is that almost all capital accumulation is driven by technological change . The logic is that without the chance to put new machinery in place, Britain would not have invested more in additional capital goods given that their marginal product was so low. Allen couples this setup with an equation in which technological change drives up profits, which are then reinvested. Somewhat unsurprisingly, given the extreme nature of the production function's parameters, technological change now accounts for basically all of the output gains after 1700. It is difficult to understand why in the absence of technological progress more capital would have been "useless"– few observers would agree that the marginal return to more capital in the UK economy in 1700 would have been essentially zero. While there is no agreement yet on how to model and calculate the interaction between capital deepening and technological progress, it is clear that *new* capital goods put in place partly to equip the larger cohorts were also *better*. Technological progress raised the marginal product of capital, while capital goods embodied much of the new technology. This complementarity between capital and technological progress is central to the historical development of the British economy.

Hand-in-hand with a greater role for capital in the economy at large went changes in business organizations. As noted, factories started to replace the putting-out system of home production gradually, and both forms of organization existed side-by-side for a long time. Textile firms, however, were small in size compared with the corporations that emerged in the late nineteenth century (Gatrell, 1977). The minimum efficient size of steel production, of chemicals plants and electrical generating stations during the "Second Industrial Revolution" dwarfed anything that went before it. Lancashire around 1850 had thousands of spinning and weaving firms, all competing vigorously with each other (Leunig 2003).One school of business historians has written about industrial development as the history of the rise of big business (Chandler 1990). Lamoreaux, Raff and Temin (2003) have argued that we should understand changes in business organization as a response to changing transport and information costs, in the tradition of Coase and Oliver Williamson. Joachim: this last paragraph is rather unsatisfactory. Can you do something about it? Do we need it?

Summary

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