Industrial Capitalism – What Veblen and Ayres add to Nef and Mantoux

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Abstract

John Nef and Paul Mantoux have richly described institutional formation resulting from the Industrial Revolution. In this paper I continue my exploration of the theme that derived demand for capital was the cause of industrial capitalism by incorporating the more theoretical work of Thorstein Veblen and Clarence Ayres.

My core research, summarized in this paper, is that the English Industrial Revolution (EIR) was primarily an energy revolution on the supply side, with fundamental aggregate demand being driven by global population growth. Prior to the energy revolution—embodied in England learning to use coal to replace wood in heating applications and muscle in manufacturing and transport applications—economic growth was supply constrained.

English inventors and entrepreneurs were pushed to substitute coal for wood because of rising relative wood prices; they substituted steam power for muscle power because of high relative wages. Compared to prior supply systems, these two changes caused an unprecedented rise in capital demand, which elicited sufficient capital supply to fuel the Industrial Revolution and create the institution of industrial capitalism. In this paper I seek to add theoretical foundations to my data-driven and descriptive approach by incorporating the work of Veblen and Ayres, and explore the theme of how institutions evolve within the general theme of "Inside Institutions."

1 Introduction

This paper explores the idea that historical institutional changes, at least the important ones, were primarily endogenous, and especially so to major economic changes. While this a very richly explored area, starting with the historical materialism school that Karl Marx furthered, I plan to contribute by extending the apparatus to microeconomic explanations, providing further macroeconomic insights, and examining historical events. My topic is large: the origin of industrial capitalism, with hints about its future.

I view industrial capitalism as a mode of production consisting of large, centrally controlled accumulations of capital used to finance the means of production for commodities destined for market, using largely wage–labor, and characterized by large scale production, accumulation, and limited private ownership.

If my basic thesis is to be seen as useful, I must show that the rise of industrial capitalism was caused by a sufficiently large economic change; fortunately, many economic and other historians

see as I do that the EIR was sufficiently large, perhaps the largest economic event in tens of millennia. The contemporaneous timing of the rise of industrial capitalism with the EIR is highly suggestive.

In order to further explore the consequences of the EIR, I here incorporate the more theoretical work of Thorstein Veblen and Clarence Ayres. As it turns out, Veblen's view of opposing cultural forces are useful to exploring a major question about industrial revolutions. The question is once the EIR genie is out of the bottle, why doesn't everyone follow the same path? Veblen describes the major forces influencing a culture as technology (progressive) and ceremonial (regressive). Ayres explores the implications of that idea. Their ideas help to answer the question.

In other work, I claim that the EIR was primarily an energy revolution. As we will see, using comparative stories of Sung China and England, I can narrate how the EIR originated primarily in changes in demand regimes and the energy economy, and how those changes led directly to the rise of industrial capitalism from the prior regime of merchant capitalism. The Sung Chinese started, but failed to complete this journey, while England succeeded.

I agree with Robert Brenner (Brenner, 1976) and E. A. Wrigley (Wrigley, 1988) that the historically large changes we call the English Industrial Revolution have a prime mover, or essentialist, explanation. I here part with Brenner's class–relations explanation, and extend Wrigley's energy transition explanation.

At best, this paper will outline a suggestion, perhaps a framework, for future research; this space is certainly one of the most well travelled among economic historians, classical institutional economists, New Institutional economists, World-Systems practitioners, and others.

2 Literature background

2.1 Historical Materialism

I will not extensively review historical materialism, except in summary for those who may have never been exposed to the idea. The kernel is that changes in material conditions such as tech-

nology and productive capacity are primary to changes in socioeconomic institutions and organization. Quoting Marx from "A Contribution to the Critique of Political Economy":

> In the social production of their existence, men inevitably enter into definite relations, which are independent of their will, namely relations of production appropriate to a given stage in the development of their material forces of production ... At a certain stage of development, the material productive forces of society come into conflict with the existing relations of production or – this merely expresses the same thing in legal terms – with the property relations within the framework of which they have operated hitherto. From forms of development of the productive forces these relations turn into their fetters. Then begins an era of social revolution. (Marx, 1904)

2.2 Recent institutional endogeneity theory

Supporting Marx, in my view, modern work arising from agricultural economics offers theories of technological and institutional change induced by changes in relative resource endowments and technology. This work is founded in microeconomics. Ruttan and Hayami have a good exposition (Ruttan and Hayami, 1984).

Whether Marx or Ruttan, macro or micro, sociology or economics, the stories are the same: economic changes cause institutional and cultural changes. There is a very large body of literature, for example the Western exceptionalism literature including Weber, that argues this causality differently. I do not review that work here, simply appealing to the fact that the contemporaneous people had either no or very dim knowledge of what the EIR was and could not therefore have foreknowledge of institutions that would be required for its success. Further, hypothesizing endogenous institutional change ahead of economic changes strains logic.

2.3 Jan de Vries from Early Modern Capitalism – a survey

Jan de Vries, in a seminal chapter in Maarten Prak's edited volume Early Modern Capitalism—Economic and soci clearly defines the great debates among the various disciplines and schools who continue attempting to explain the English Industrial Revolution.

de Vries' chapter, "Economic growth before and after the Industrial Revolution – a modest proposal," explains the contours of the debates, and in the end argues for a broad historical approach rather than one dominated by a particular school of thought (de Vries, 2001).

The structure of his thinking is so clarifying that I start with it as an organizing framework in my work here whose goal is to illuminate the rise of industrial capitalism, and investigate its primal cause – institutions (including culture) or economics; of course both happened, but I wish to see if there is a clear primal driver. I land in a different place than de Vries.

2.3.1 Different modeling schools produce an ahistorical approach

de Vries opens by analyzing the problems in past and current approaches: "Coherent accounts of historical economic growth are difficult to achieve only in part because of the venerable jurisdictional boundaries that have for so long governed the training of professional historians" (de Vries, 2001, p.177). This causes different story tellers for eighteenth (early modern) and nineteenth (late modern) histories, and thus at least the potential for different stories.

de Vries continues: "One might suppose that what historians tear asunder with their conventions of periodization, economists would stitch together with the healing balm of theory" (de Vries, 2001, p.177). But, before the neoclassical era, economists applied classical models with some binding constraint, usually land, whether the modeller followed Smith, Malthus, or Ricardo in details. Later neoclassical modellers assumed constant returns to scale, substitutability at all margins, and technologies freely available to all, and thus told a story abstracting from all time and space—no history, no geography. And thus he introduces his case for a more integrative approach to fix the rifts in both historical and economic story–telling, an approach I attempt to extend.

2.3.2 The Industrial Revolution

de Vries examines the revisionist version of the EIR, and then proceeds to examine the "bookends." Here, I summarize de Vries' key arguments:

Commenting on the commonly-held neo-classical model's "bookends" of the EIR, meaning the neo-Malthusian model that preceeds it, and the Kuznetsian model of modern economic growth that follows it, a unitary growth model with a single long term trend, de Vries accepts the revisionist criticisms from many including Mokyr (1993), Jones (1988, p.26), and Crafts and Harley (1992). The revisionists claim the EIR covered a longer period, and a slower rate of growth than Kuznet's version. But de Vries does not fully dismiss his bookends, instead appealing to the complexity of the event and saying that we must revise those models. I agree. Along they way, de Vries dismisses as unhistorical and unempirical the neoclassical "Solow" convergence models. While complex, my view is that most narratives are also un-economic, a puzzling oversight given the people telling the stories. Again, I hope to contribute to correcting this oversight.

2.3.3 Modern economic growth

First, de Vries sketches the contours of modern economic growth, post Industrial Revolution, using the seminal empirical work of Simon Kuznets, Phyllis Deane and W. A. Cole, and Angus Maddison. He supports the empirics with the neo-classical growth theory represented by Robert Solow's work. These works unarguably describe a structural break from the prior rate of economic growth, supported by a growth theory that demands technological change for its growth engine. The facts clearly support this story.

2.3.4 The neo–Malthusian model—pre–industrial growth

Next, de Vries outlines the pre–Industrial Revolution neo–Malthusian models. He cites a large number of contributors including François Simiand, Wilhelm Abel, Ferdnand Braudel, Michael Postan, E. H. Phelps Brown and Sheila Hopkins, B. H. Slicher van Bath, Emmanuel Le Roy Ladurie, and importantly, the team of E. A. Wrigley and R. S. Schofield. The consistent essence of this model is that movement in populations, fueled by sexual relations, is the dominant economic relationship and is always constrained by a more–or–less fixed supply of land to feed the population and an agricultural technology at it's frontier (de Vries, 2001, p.181). Pausing the de

Vries narrative, I turn to that of E. A. Wrigley on the Malthusian world—with Wrigley bringing clarity to that story.

E. A. Wrigley models this world with useful components; he describes the world in, among other references, People, Cities and Wealth. The main components of the Wrigley model include living standards (most often represented as Gross Domestic Product per capita), nuptiality (marriage) rates and ages, and fertility rates. In the neo-Malthusian world, before about 1880 in England, there is a strong positive correlation between living standards and nuptiality rates, and subsequently a very strong positive correlation between nuptiality rates (and age at first marriage) and fertility rates. In this world, as living standards fluctuate upward due typically to exogenous factors such as better weather and crops, more women marry at a younger age, and therefore increasing fertility rates drive up population levels.

Wrigley's (and Scofield's) (Wrigley, 1987, p.237) major correlations for his neo-Malthusian model for England are summarized as follows:

Factor 1	Factor 2	Sign of correlation
Population increase	Food prices increase	Positive
Food price increase	Real income decrease	Negative
Real income decrease	Nuptiality decrease	Positive
Nuptiality decrease	Fertility decrease	Positive
Fertility decrease	Population decrease	Positive

Thus rising population caused lower living standards and retarded fertility through the nuptiality mechanism. Wrigley claims a different mechanism for China's version of a neo-Malthusian model as in:

Factor 1	Factor 2	Sign of correlation
Population increase	Food prices increase	Positive
Food price increase	Real income decrease	Negative
Real income decrease	Mortality increase	Negative
Mortality increase	Population decrease	Negative

Wrigley summarizes the "Chinese" version of his model this way: "Here to balance the books[,] nature audits with a red pencil" (Wrigley, 1987, p.236). This neo-Malthusian variant was not the most pleasant of existences.

The fundamental importance of Wrigley's theories is that they fit the historical data that we know describes the millennia preceding the EIR in terms of population and living standards, and suggest how radically these changed post-Revolution. The history is of increasing total final demand because of gradually rising population and, cyclically, rising living standards. But the rising final demand eventually ran into some constraint or set of constraints that caused living standards to fall.

Only in the late eighteenth century was this perpetual cycle interrupted, allowing simultaneous increases in both population and living standards. Total final demand started marching inexorably upward and the supply revolution that was the EIR was able to continually match the population's rising desires and incomes for the first time in history.

de Vries further covers, de rigueur, the contributions of Michael Postan and Emmanuel Le Roy Ladurie. These are important contributions; Wrigley, however has both the theory and data that is convincing.

Surveying this extended era of preindustrial growth, de Vries summarizes that, given the "revised view of British macro-economic performance during the Industrial Revolution..." (less than earlier estimates) "...would appear to required that significant preindustrial growth took place in the long run" (de Vries, 2001, p.188-9). He cites contributing factors to this secular

growth as including institutional development, urbanization, demographic control mechanisms, market expansion, agriculture, industrial organization, and technology. These surely are important developments, but as of yet, there is no primal contributor. That is a defect that de Vries next notes, and I attempt to correct.

2.3.5 From two models to one

de Vries approaches the great question, how to explain the miracle of the EIR, by quoting from David Landes (Landes, 1993): "In a polemic directed against revisionists of the Industrial Revolution, David Landes excoriates economists in general and Cliometricians in particular for being 'passionate seekers after the One Cause, the prime mover.' He (Landes) observes that these methodologically sophisticated economists forget that everything is substitutable and hence nothing is indispensable," ... and praises the approach of 'multiple causation' (189).

de Vries further comments that "Landes fails to acknowledge that the search of the One Cause of the Industrial Revolution arises from the need to explain the lifting of the great constraint that defines the neo-Malthusian model" and then invokes Wrigley as a champion of the 'essentialist' approach (de Vries, 2001, p.189). Indeed.

He then describes the gradualist approach and then, amazingly to me given how far he travelled in this chapter, makes the case for a centrist approach, basically ignoring my (and his?) reading of Wrigley's core essentialist message in "Continuity, Chance and Change" (Wrigley, 1988).

2.4 Nicholas Kaldor weighs in

Kaldor, in his 1970 The Case for Regional Policies, attempts to explain the large regional differences in development rates and comments on the essentialist version of history. He verges on declaring economics primary; after absorbing Nef and Mantoux, I make the stronger case.

> ... industrial production requires a great deal of capital–both in terms of plant and

> machinery, and of human skills, resulting from education–but in explaining such differences in 'capital endowment' it is difficult to separate cause from effect. It is as sensible–*or perhaps more sensible* (my emphasis)–to say that capital accumulation results from economic development as that it is a cause of development. ... Accumulation is largely financed out of business profits; the growth in demand in turn is largely responsible for providing both the inducements to invest capital in industry and also the means of financing it. (Kaldor, 1970, p.339)

2.5 Veblen extends the story

Thorstein Veblen has important things to say about the evolution of industrial capitalism after the EIR, and opines on its future. In The Theory of Business Enterprise he documents "pecuniary interests" capturing industry (the standards-enforcing machine process) by exercising their individual incentive to disrupt the system toward the end of consolidation (monopoly power). He claims that, for the first time in history, this process of what we might today call financialization has separated productive interests from social or community interests to the detriment of the society. The old institutions such as blood–relationships, citizenship, or church are replaced by pecuniary and ownership interests. Further, individualism is suppressed under the standardization pressures of the machine age as rote work affects many aspects of a workers life.

Veblen has an interesting perspective on the future of capitalism that I will address later in this paper.

2.6 Ayres emphasizes and clarifies Veblen

Clarence Ayres in Theory of Economic Progress crystallizes and develops some of the more important points of Veblen. In particular as it bears on this article is the clear distinction between technology, the progressive force in society, and ceremonialism, the conservative or regressive ideological force in society. And he makes the important claim that they always coexist.

Ayres further makes the point that while technology includes tools, tools are not technology, and that human skills and tools are always paired. This last assertion has become increasingly

problematic as a skilled programmer can write code one time that controls the tool, decreasing or eliminating the need for ongoing human skills.

For Ayres, while markets existed before economies, an economy is not market–conceived, but instead is technology–conceived. He further attempts to account for the EIR by asking "what situation could have given rise to so vast a technological revolution?" (Ayres, 1962, p. xvii). He requires a unique sort of combination of technical culture traits with a uniquely fluid institutional situation.

Commenting on the vast cultural revolution since the EIR, he says its propelling force has been technological. But, institutional circumstances have been a causal factor of equal importance. So he must conclude that institutions are at times ceremonial and thus regressive, and at other times can be progressive. These thoughts will be particularly useful later in answering the question I posed above about why all economies are not fully developed once the English let technological genies escape their bottles.

In the remainder of this paper I try to strengthen the essentialist message, which then leads directly to the rise of industrial capitalism. I first develop a very basic theory of the EIR which applies also to China, and perhaps to other pre-modern industrialization attempts such as the Dutch Republic during the sixteenth and seventeenth centuries. If supported, this then is progress toward a general theory of industrial revolutions and industrial capitalism.

3 Industrial revolutions

In other work, I provide a theory for industrial revolutions, centered on the EIR. There I claim and demonstrate empirically that the EIR was essentially an energy revolution in the strong sense that without the energy revolution there would not have been an event which has come to be called the EIR.

The core elements of this theory are in the Technical Appendix, Section 9.

Summarized, the story unfolds this way. There was an up welling of populations and thus

total incomes during the Middle Ages; this is temporally related to the Medieval Warming Epoch which increased (likely globally) agricultural yields and influenced institutions and culture. Increased goods and services demand led to increased production in heat-consuming industries such as smelting, metal working, salt making, dyeing, and brewing. Heat consuming industries used mainly wood (sometimes as charcoal) as their energy source. The wood demand deforested neighborhoods, regions, and countries. Wood prices rose dramatically, for example in sixteenth century England. This also affected household uses of wood for heating and cooking.

Producers and households naturally sought alternative energy sources. In England and China, that source was coal. Using coal for heating was not an easy technological transition for many reasons; the full transition was on the order of centuries. In the Dutch Republic, the energy source was peat. The Dutch ran out of peat supplies and their industrialization attempt stalled.

In pre-modern eras, this was the path to an industrial revolution, the transition from an inherently limited energy source, trees, to an essentially unlimited source, coal. Both England and China did this, and further research should show that other areas in addition to the Dutch Republic did as well. But this is only the first step on the path.

The main leap to an industrial revolution, exemplified in the EIR, was learning to substitute the new energy source not just for the heating industries, but through the application to steam-powered devices to supplant human and animal power. This invention unleashed the enormous productivity gains and scale that are the hallmarks and legacy of the EIR.

Of course, I still need to explain what was unique about England, but this is sufficient background to delve into the foundations of industrial capitalism, which was not uniquely English at its roots.

4 The rise of the demand for capital and its supply – the path to industrial capitalism

4.1 Transition from wood to coal for heating - England

In the "real economy" story of the previous section, we have clues that explain how the demand for capital arose, which when paired with the capital supply story, will give us a picture of the economic foundations for that institution. First the demand side, and first for England.

John Nef plays an important role in this story. Nef, a University of Chicago historian, produced in 1932 a two-volume work titled The Rise of the British Coal Industry. This is a little-cited work in recent scholarship; scholars should seek it out – this is as definitive a work as one could hope for (Nef, 1932).

In Volume I, Part IV, Chapter I, Nef lays out the case for the necessity of the development of capitalism to support the level of investment needed in the nascent coal industry. Nef dates the start to the mid-sixteenth century, along with the rise of using coal as a heating fuel. He discusses that the division of labor in the mining and transportation of coal was great, calling a mine, or colliery, "a Jack of all Trades shop" (Nef, 1932, p. 348). And most of this labor was wage-labor from workers who depended entirely on wages for their living, a signature feature of capitalism. I will quote Nef as he captures the state of capitalism across the continent as well as in England.

> There was no other British industry of equal importance which had advanced so far on the road to modern capitalism. This observations leads naturally to the question : How far does the expansion of the coal industry in Great Britain at an earlier period than in any other part of the western world account for the fact that the new capitalistic order, which, before the reign of Elizabeth, had found more fruitful soil in Italy, Flanders, and southern Germany than in England, should have obtained, during the seventeenth and early eighteenth centuries, a tighter hold on the economic life of England than on that of any continental country? How far, in other words, is the growth of modern capitalism as the dominant form of economic organization related to the rise of the coal industry? (Nef, 1932, p. 349)

Now while I would prefer from Nef a clearer separation in this discussion between the demand

for capital and the supply of capital; as he progresses, he clearly is developing the case for demand for capital in what I call the first step of the EIR, the transition from wood to coal heating.

Good enough; in the following pages he relates the large costs of exploratory drilling, deep structural requirements (up to 36 fathoms), and drainage requirements, sums far beyond the resources of a few workers to supply on their own. He relates many cases of individual investments (capital supply), and concludes the section on the capital requirements of coal mining by saying "For the first time in western Europe, in connection with an industry employing a considerable portion of a country's population, large capitals had become the rule" (Nef, 1932, p. 380).

To summarize, this effect begins in the sixteenth century and grows dramatically in the seventeenth and eighteenth centuries, preceding the dating many other estimates claim for such a beginning. Are we yet at what we might recognize as industrial capitalism? No, but we have in coal mining an engine of demand for capital that leads inexorably to nineteenth century institutions.

To further bolster the case, Nef elaborates on the even higher capital requirements for transporting mined coal; after all the early mines were in north east England, far from London and other consumption centers. This required capital investment in boats, wharves, warehouses, wagons, and roadways.

The demand story is straightforward for Nef. The capital supply required came mainly from wealthy merchants and nobility. Thus the story of the rise of merchant capitalism that had, relatively, low capital demand and high capital accumulation (supply) is important. Eric Mielants, in his The Origins of Capitalism and the "Rise of the West", makes the strong case for a rise in merchant capitalism among the western European city-states between A.D. 1000 and 1500 (Mielants, 2007). I will accept his results without further analysis as supporting my claim for the sufficient supply of capital.

This first phase of the EIR has given us, then, two critical pieces of infrastructure – the technologies and physical infrastructure for the mining, transportation, and consumption of coal, and a financial institution, merchant capitalism, capable of supplying the comparatively large

capital needs of the physical infrastructure.

4.2 Transition from wood to coal for heating - China

The story emerging from Sung China is not yet as rich or well-documented as that of England. But it is sufficient to detect similar mechanisms at work. The story is mainly told by John Hartwell, a student of Nef, and a sinologist.

I will ask Hartwell to start our story with the following:

> From about 750 to 1100, China experienced a series of economic changes roughly comparable to the subsequent patterns of European growth from the Crusades to the even of the French Revolution. The spread and use of money, development of new credit and fiscal institutions, increase in interregional and international trade, and colonization of hitherto marginal land which took place in the Occident during the half-millennium preceding the Reformation was paralleled by an earlier era of progress in East Asia during the two-hundred-fifty years from the rebellion of An Lu–shan (755) to the treaty of Shan–yüan (1004). And the achievements of late sixteenth– and early seventeenth–century England, which John Nef terms an "early industrial revolution," were in many respects even exceeded by the impressive expansion of mining and manufacturing in eleventh-century China. (Hartwell, 1966, p. 29-58)

Supporting his hypothesis of rising per-capita incomes, Hartwell notes about the eleventh-century, "... alum making, salt processing, quicksilver and cinnebar production, shipbuilding, papermaking, and printing were all businesses in which the scale of operation and the absolute level of physical output were greater than was common in any other national economy before the last decades of the eighteenth century. But progress in the extraction and refining of metallic ores was even more astonishing ..." (Hartwell, 1966, p. 32). Hartwell continues by describing the high technical state of Chinese iron-making technologies using blast furnaces fueled both by anthracite coal and coke. Wood and thus charcoal became increasingly scarce as population and industry expanded.

So we have a similar story in China about the first step of an industrial revolution—the transition from wood to coal for heat–using industries facing rising aggregate demand, especially

iron and steel making in the Sung dynasty, driven by increasing lack of wood availability through deforestation (Hartwell, 1966, p. 50).

Hartwell clearly shows that the mining and metallurgical industries were private, and the thirty–six large mining and iron and steel operations during the Sung were owned by thirty–six wealthy families. Here, the demand for and supply of capital were controlled by the same entities. Hartwell claims a lack of evidence on the source of the wealth of these families, but provides evidence that most of these families were landed gentry (Hartwell, 1966, p. 47); he does speculate that some of the capital supply may have been through wealthy merchant capitalists. If so, this is a similar supply and demand story as in England, with the capital supply called forth by the demand from the mining of coal, and in the Sung case, applying that to large-scale production of iron and steel.

To summarize, both early–modern England and Sung China before the Mongol invasion experienced an energy revolution—the transition from wood to coal to fuel heat–consuming industries—causing structural changes in the economies. Large capital supplies were needed to support the large and centralized infrastructures required to mine and transport coal. That demand for capital was met by both landed gentry and merchant capitalists. This may mark an important transition toward industrial capitalism—the large–scale application of accumulated capital toward economically productive investments driven by an energy revolution; this is the first step towards industrial capitalism.

Next, I will examine the second phase of industrial revolutions.

4.3 Industrial revolutions—second phase

In other work I claim that the second stage of an industrial revolution is the transition from animal power, mixed human and other animals, to mineral (carbon) power. This is exemplified during the EIR by the increasing substitution of steam power for animal power for both production and transportation. This promotes a great increase in labor productivity, and, given distribution, living

standards. A key invention is, of course, the steam engine. While China knew of steam engines by at least the seventeenth century (Wang, 2009, pp. 31-54), they did not apply them to practical applications until the nineteenth century.

However in England this was not the case. After making the wood-to-coal heating transition, England made the human-to-machine power transition, increasingly taking advantage of the enormous supply scalability of coal-fired steam engines.

I further claim that the English had strong economic motives to apply machine technology as a substitute for high-wage English labor throughout much of the early-modern era. My argument extends the work of Robert Allen The British Industrial Revolution in Global Perspective (Allen, 2009) in this historical space. The Chinese had no such incentive – wages are thought to be low during the relevant historical periods.

This application of economic incentives is sufficient, I claim, to explain why England completed their industrial revolution and China did not—the Chinese had no equivalent economic incentives.

In any case as England proceeded down the path toward the EIR, the demand for capital increased. Capital was now required for building the new steam-powered factories and the steam–powered land– and water–transportation systems. So, again, we have an energy revolution causing the derived demand for capital to increase dramatically. By this stage in English history (eighteenth century and later), financial systems were increasingly participating in creating credit to supply the inventors and entrepreneurs with needed capital.

4.4 Transition away from muscle power

This history is masterfully told by Paul Mantoux in The Industrial Revolution in the Eighteenth Century (Mantoux, 1961). Mantoux, from France, published this in the original French in about 1907; the first English translation was 1928 and I refer to the 1961 edition. Mantoux is another great historian who is under-cited by contemporary economic historians to their detriment. Rather than

rely on me to present his credentials, I will quote from T. S. Ashton in the preface to the 1961 edition:

" . . . in both its architecture and detail this volume is by far the best introduction to the subject in any language. It is, moreover, a permanent work of reference. . . . It is astonishingly fresh. And not a few of the findings of modern writers that one had thought of as new are now seen to have been anticipated by M. Mantoux. His book is one of a few works on economic history that can justly be spoken of as classics" (Mantoux, 1961, p. 23).

Mantoux draws a constant and clear distinction between "manufacture" and the "factory system." Manufacture is to him the centralization and division of labor; the factory system expands upon that by using machine power instead of labor power. Woven throughout is the role of first the merchant capitalists, and then that of the great landowners in this centralization of labor and its mechanization, including the transportation infrastructure required for the correlative expansion of exchange (trade). Mantoux covers in great detail the ways this evolution of production affected the "whole economic system and consequently the whole social system, which is controlled by the growth and distribution of wealth" (Mantoux, 1961, p.25). That story, while crucial, is not my specific focus here.

The industries Mantoux cites include the woollen industry during the Renaissance starting in the the fourteenth century, and the seventeenth and eighteenth centuries. Specifically, he relates "the existence of capitalist undertakings, particularly in the woollen industry, and the beginning of the sixteenth century and even in the fifteenth and fourteenth" (Mantoux, 1961, p. 33). Further describing that development, "Instead of being mere merchants, buying cloth from the weavers and selling it in markets or at fairs, they [rich cloth merchants in the north and west of England] set up workshops which they supervised themselves. They were manufacturers in the modern sense" (Mantoux, 1961, p. 33). I interpret this story as clear evidence of early roots of English industrial capitalism. One must next ask, why would these merchants travel this path, what were the expectations of the future of their business that motivated them? While Mantoux does not directly address the growth of demand that surely must be behind the merchants activities, he

talks about a proxy for that.

That proxy is commercial expansion starting before and during the early modern period. A great deal of history is written on this topic. I again ask why would such a commercial expansion arise? Was it *sui generis*? Almost certainly a major cause here was the increase in populations in, at least, the countries comprising the trading world. As a simple illustration of rising populations consider figure 1 composed from Angus Maddison's database and, after 2008, UN data.

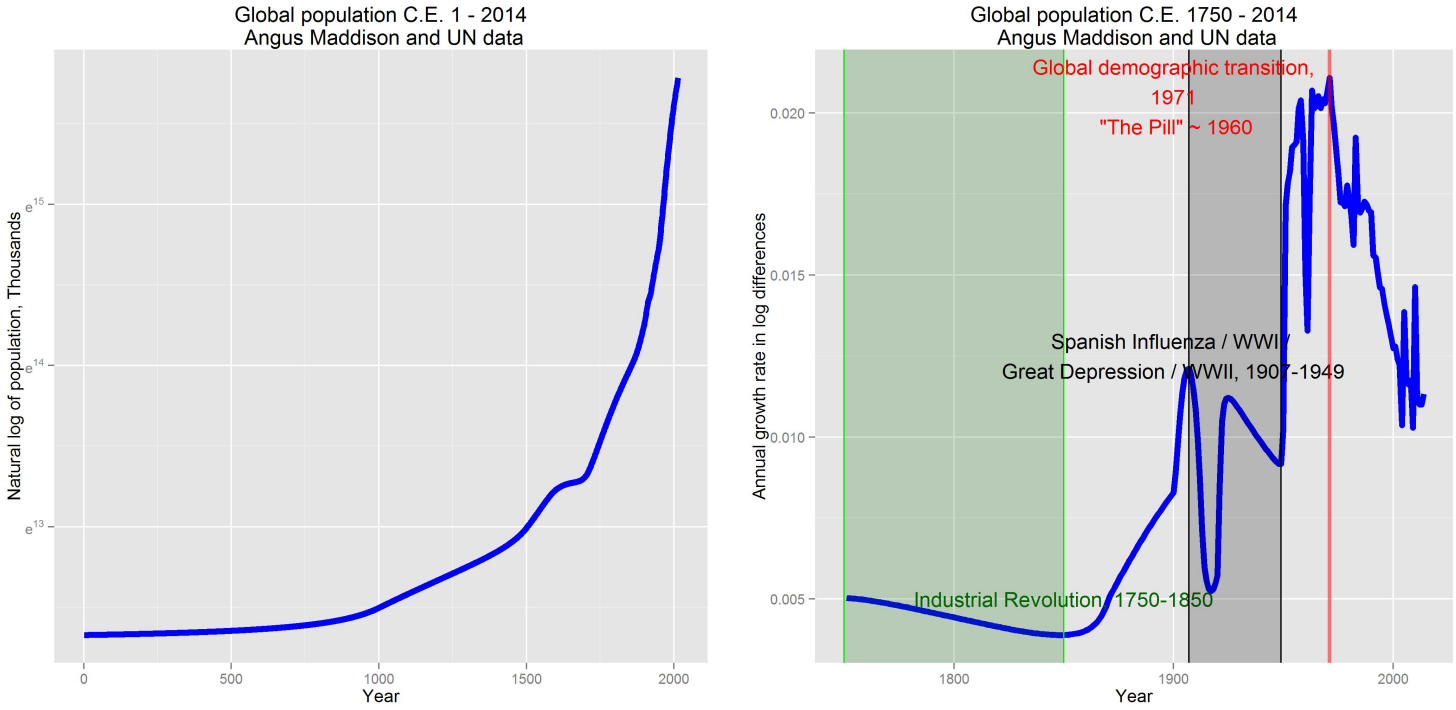

Figure 1: Angus Maddison and UN: log and log differences of global population

The left panel of figure 1 displays the log of population levels since year one. This is super-exponential growth, with barely visible wiggles. This population, and thus aggregate demand, growth dynamic drove the supply side into the EIR and created industrial capitalism. The right panel is in log differences of annual population levels since 1750 (a common starting date for the EIR), so shows annual growth rates. Note that the growth rate peaked in 1971 at 2.2 percent, has declined to about 1 percent now, and appears poised to head, perhaps much, lower. If population growth was the underlying cause of industrial capitalism, then we must question the implications

of its plummeting growth rate. I do so in a conjectural section in paper three.

One can clearly see the goblal population liftoff in the late middle ages, accelerating during the early modern period, and "going exponential" during the EIR. England's population growth follows this pattern. I claim that population growth essentially everywhere in the world is sufficient to account for the demand expansion that the commercial expansion, first in the Dutch Republic then England, required in order to bloom. I note that perceptible per–capita gains to total output do not happen until after 1500 in Western Europe, and the great gains in living standards await the second–phase EIR in the nineteenth century. Now that we have a sufficient story for ever–increasing demand, we can return to the supply side which limited growth in a pre–EIR world.

Mantoux analyzes land redistribution in England, focusing on the enclosure movement. This episode is fascinating and important in that it freed agricultural labor to urbanize and fuel the EIR and, as a by-product, raised agricultural productivity. While not central to my story here, I believe I can, in future work, make a claim that it was early industrialization in the woollen industry that motivated the enclosure movement. For now, we move on.

Mantoux traces the beginnings of machinery in the textile industry and the role of capitalist undertakings resulting in the rise of the factor system. He discusses the technologies, such as the knitting frame and the silk throwing mill, and their inventors in detail. This includes a fascinating narrative on the transition from tools to machines that changed the nature of labor, described as essentially a skill transfer from man to machine, that initially used wind and water power but enabled the application of steam-power when that was feasible (Mantoux, 1961, pp. 189-191).

He relates the canonical story of John Lombe pirating Italian silk-throwing technology and using it to build a very large (five hundred feet long and five or six stories high) Derwent factory that was centrally powered by a water wheel. This was in about 1718, and illustrates the three key points: the skill transfer from men to machine, the power transfer from men or animals to something much more scalable, and the demand for capital to realize this achievement. John's brother Thomas supplied that capital; the capital source is likely from Thomas' merchant activities. The

factory employed about three hundred workers (Mantoux, 1961, p.191).

This clearly was the prototype for the future of the factory system in cotton and woollen textiles and thus heralded the course of the EIR over the following 150 years. The more famous inventors/entrepreneurs, John Kay (fly shuttle), John Wyatt (cotton spinning machine), William Hargreave (spinning jenny), Richard Arkwright (water frame), and so many others, built on this successful factory template, built the EIR, and greatly increased the demand for capital.

The factory system was a fertile ground for the application of steam-power; this loosed the constraints of finding a suitable water-power location, or unreliable wind power source, and thus began the essentially uninterrupted productivity rise leading to ever-increasing per-capita living standards. This also led to the revolution in land transportation represented by the railroads, and the maritime transport revolution of the steam ship. And, naturally, led to a great increase in the demand for capital.

While aggregate capital stock data seems somewhat sparse for the era, a simple illustration will show the growth-rate leverage capital had as growing population demands drove aggregate output.

A 1984 Journal of Economic History article by Jeffrey G. Williamson, "Why Was British Growth So Slow During the Industrial Revolution?", provides a survey of capital growth rates and, importantly, estimates through time of the Capital/Output ratio. Williamson draws on work by Phyllis Deane, Floud and McCloskey, and Simon Kuznets. I partially reproduce his table (Williamson, 1984, p. 701) as Table 1:

Table 1: British capital productivity. Source: Jeffrey Williamson (Williamson, 1984, p.702)

Period	Capital's productivity Y/K	Calculated K/Y
1761–1820	0.36	2.78
1791–1820	0.38	2.63
1821–1860	0.53	1.89

So before 1820, for every additional British pound of aggregate output, more than 2.6 British pound's worth of capital stock was required. I will not here recount the growth in Gross Domestic

Product estimates for that period except to summarize this is the period that GDP growth rates went exponential in Britain. I note that while growth rates of GDP and capital will be the same, the capital growth rate operates on a large base such that capital accumulation is increased at the multiplied rate.

It does not appear either from Nef or Mantoux that capital supply was a real constraint, with investment flowing from wealthy merchant capitalists, wealthy landowners (often nobility), and eventually a banking system. Instead, capital supply appears to have been called forth by capital demanded to keep up with aggregate demand growth and the technical productivity factors summarized by the K/Y ratios in the table.

Thus we have a straightforward supply and demand economic story for the rise of industrial capitalism. This was facilitated by the fact that capital stock is consumed only over many units of output, thus the relative mathematical ease of building large capital accumulations during the nineteenth century.

5 The primary roles of capital in the EIR

Tangible capital has two primary roles in the EIR:

The first is the infrastructure investment required to extract and transport coal as a fossil energy source used initially to substitute for ever more expensive wood-supplied Joules in heat-using applications. Increasing demand caused deforestation, causing rising wood prices. Compared to using wood as the primary heat source, English coal supplies were distant, deep, wet, but ultimately cheaper than wood. As John Nef documents (Nef, 1932), the investment required for successful coal extraction and distribution was large and historically unprecedented.

The second is to replace muscle–supplied power inputs to the production process with steam-powered mechanical devices. The energy input is largely from coal during this revolution, so the tangible capital devices use fossil inputs to provide power in the form of, typically, rotating or reciprocating motion through the mechanical application of steam – the steam engine.

There is an important class of mechanical devices—gears and levers, say—which amplify muscle power by allowing increased muscle power input for a given output, allowing low–intensity muscle power to leverage up their power inputs to accomplish higher-intensity tasks. Note that this requires added muscle Joule inputs for a given amount of output, recognizing humans have fixed potential power output per unit of time; this is not the kind of capital device I focus on here which allow essentially unconstrained power inputs per unit of time. Such pure mechanical muscle assists are not the important technologies in the second phase industrial revolution.

As I cite in this article, Paul Mantoux describes this revolution in great detail, using the steam-powered mechanization of both the English woollen and cotton textile industries as primary examples (Mantoux, 1961).

There were non–coal non–muscle power inputs to manufacturing through much of recent history. These were either water– or wind–powered rotary machines and were precursors to steam-powered machines. In recent scholarship, Örjan Wikander claims "Today, we may state with confidence that the breakthrough of the water-powered mill did not take place . . . in the early middle ages, but rather . . . in the first century A.D., or perhaps even slightly earlier." The water wheel was known and used during the late Roman republic or the early empire (as cited in (Temin, 2012, p. 224)). Of course, the Arkwright water frame was an EIR water-powered mechanical cotton spinning device, but the true energy revolution started when the essentially unconstrained scale of steam power was applied through such devices to manufacturing processes.

Note that in my theory of industrial revolutions (formalized here 1) capital is always labour substituting since, while the Joules of energy which are inputs to production are either muscle or fossil inputs but, for each Joule, not both, tangible capital applies fossil Joules to industrial processes. They are mutually exclusive. Of course, both organic and inorganic energy input sources for a production process can be mixed, and it is this frequent case that causes the "complements" versus "substitutes" confusion.

To crystallize the starkness the energy revolution represented in choosing among energy input

sources, I summarize briefly from Fred Cottrell, who wrote "Energy and Society" in the mid–twentieth century: Cottrell sharply contrasts low–intensity and high–intensity energy regimes and societies. Low intensity "converters" include human and animal power using plant–based input sources, and water– and wind–mills (Cottrell, 1955).

The first high–intensity converter in Cottrell's history is the sailing ship, which provided at least an order of magnitude increase in energy surplus over low–intensity converters, and dramatically changed the economics and institutions of the world's economies.

Cottrell then continues to recognize that the most disruptive high–intensity converter was the steam engine, the signal technology of the EIR. The steam engine disrupted the economic systems and, thus, their social systems and institutions, a legacy of turmoil that continues to this day.

6 Summarizing the story

First-stage energy revolutions, the transition from wood to coal for heat-consuming industries and households, require substantial capital to (invent and) build extraction, transportation, and production infrastructures. Before this, there was likely no large-scale demand for capital or, from a different point of view, the industrial scale made possible by industrial capitalism was not required to meet market needs. This type of energy revolution occurred at least in China during the Sung dynasty (ninth–, tenth–, and eleventh–centuries), and in early–modern England.

England built their second–stage energy revolution on their first–stage infrastructure, using a mechanized factory system converted to steam power to dramatically increase labor productivity. China did not. Until the modern era, this was the only known complete industrial revolution, was accompanied by greater demand for capital, and led directly to the institution we now call industrial capitalism.

This paper seeks to identify a prime–mover in the explanation of what is a very complex social system, industrial capitalism. Following the suggestions of Historical Materialism and

endogenous institutional theory that depend on economic causes, the seminal change in demand for capital was the energy revolution that required replacing increasingly scarce and expensive wood with more capital-intensive coal for heating, and then, with ever more sophisticated technology, replacing labor power with coal power. Thus, I suggest these energy revolutions are the prime–movers in the rise of industrial capitalism.

7 After the EIR genie, why not everyone?

Development economics has not been the most successful branch of economics from an applied policy standpoint. It appears to be very difficult to advise an underdeveloped country how to develop. What Ayres adds to an explanation for this is the very Veblenian dichotomy between technology and ceremonialism.

Ayres makes the point that ancient, and especially densely populated, cultures show great resistance to change—the regressive nature of ceremonialism, and thus have difficulty mounting technological revolutions (Ayres, 1962, p. xix). I think this is largely correct. But given my theory of industrial revolutions, I would further generalize Ayres' premise in this way:

Technological revolutions will be able to overcome ceremonial resistance if either: a) There is sufficient economic pressure to do so. The canonical example is England and the EIR; or b) some exogenous institutional change occurs that is able to overcome ceremonial resistance. I think of examples of either authoritarian capitalism such as Japan, the four "Asian tigers" (South Korea, Taiwan, Hong Kong, and Singapore), and recently China itself; alternatively there are a few cases of authoritarian socialism—one thinks of the Soviet Union which was highly successful at the time Ayres was writing. Most examples of "developmental states" are examples involving an authoritarian regime.

Failing either of these cases, it becomes very unlikely that a technological revolution will happen because the only path to increase living standards goes through increased labor productivity. Increased labor productivity is caused by the many technologies that apply energy inputs to the

production process. Without English–like economic parameters or the benevolent dictator (or army), that is not going to happen. Development advisers who promote just institutional change (property rights, financial systems, and so forth) will almost surely fail.

Ayres recognizes that there was low ceremonial resistance in the "western offshoots" of the United States, Canada, Australia, and New Zealand; it is also true that, in key respects, they had English–like economic parameters (cheap resources including energy, and high wages).

Note that few African countries have either of the technological revolutions requirements.

If this hypothesis is true, development economists should recommend finding a benevolent dictator that understands how important energy consumption is to industrial, or technology, revolutions.

8 Brief conjectures on the future of demand for capital and industrial capitalism

The coal and steam revolutions required large investments in centralized structures and infrastructures. Current energy extraction, processing, generation, and transportation investments remain large and highly centralized. Should a future energy revolution result in highly distributed and very inexpensive energy sources, the need for large capital investments will be diminished. The author believes these radical energy technologies are in train; that discussion should remain outside this paper.

The factory system added to the demand for capital with large centralized automated manufacturing dominating the nineteenth and twentieth centuries; global supply chains have somewhat distributed manufacturing infrastructures, but they remain capital intensive. We are living through the very beginning of a revolution in manufacturing, 3D printing, that holds the promise of a highly distributed, even consumer based, manufacturing system that will be much less capital-intensive.

These possible trends will be enhanced by a likely peaking of global population in this century; the driver of the original EIR will therefore be removed. Total output will fall.

I illustrate this in the right panel of figure 1. This transformation of the population levels displays the change in the annual population growth rates. For my argument here, there are two noteworthy features:

- Until about 1971 and dating to, likely, at least the beginning of the Neolithic Era, population growth rates had a positive second derivative, so always increasing growth rates to levels above two percent per year at the peak. This, under my theory, implies ever-increasing demand for capital.
- Since about 1971 that trend has (strongly) reversed, and we note since then that population growth rates have a negative second derivative. While the first derivative is still positive (population levels are still increasing), this reversal will have profound consequences. For my current argument the implication is that global aggregate demand will eventually peak, then decline. Under my theory of industrial capitalism, demand for capital must then also decline.

Whether these trends will be sufficient to diminish the rentier power of industrial capitalism remains to be seen, but at the very least this is an intriguing possibility. If the demand shrinks, so will the supply, and thus the accumulated power of capitalists can begin to fade.

8.1 Veblen's speculation on the future of industrial capitalism

Veblen is not sanguine about the future of capitalism. His logic goes as follows:

The main values to which Veblen attributes English economic development are Lockean natural rights (Thorstein Veblen, 1904, p. 80). The modern "credit" (financialized) economy subverts those values. As he wrote, his judgment was that there were enough ancient norms of Western Christendom intact to temper the trend. But those would dissolve into materialism over time, and the business enterprise would eventually fail.

A very interesting projection; however if one looks around, business enterprises are more powerful than ever in their trans–national cloaks.

However, my story of eventual declining aggregate demand, an economic story rather than an

institutional one, is going to cause global capital problems

9 Technical Appendix

9.1 Importance of energy for growth and development

Period	Pearson Correlation Coefficient: energy and GDP
England 1300-1873	0.998
World 1980-2008	0.993

Table 2: Energy/GDP correlations – the case for energy revolutions

9.2 Cross-country history of energy consumption

Year	England	China	Netherlands	India
1650[a]			0.63	
1820	0.61			
1840[a]			0.33	
1870	2.21			
1970[a]			8.07	0.33
1973		0.48		
1998[b]	6.56	1.18		
2008[b]	5.99	2.56	9.86	

Table 3: Per-Capita Primary Energy Consumption, annual Tonnes of Oil Equivalent. *Source:* Angus Maddison, [a]de Zeeuw, [b]US DOE EIA

9.3 Theory of industrial revolutions

$$\frac{\text{Marginal Product}_{\text{wood Joule}}}{\text{Price}_{\text{wood Joule}}} \ll \frac{\text{Marginal Product}_{\text{coal Joule}}}{\text{Price}_{\text{coal Joule}}} \tag{1}$$

First-stage energy revolution: China 900 – 1200 (Northern Sung);

England 1590 – 1700

$$\frac{\text{Marginal Product}_{\text{labor Joule}}}{\text{Price}_{\text{labor Joule}}} \ll \frac{\text{Marginal Product}_{\text{steam Joule}}}{\text{Price}_{\text{steam Joule}}} \tag{2}$$

Second-stage energy revolution: England 1700 – 1873, but not in China

The RHS of (2) was so large that it induced a major positive aggregate supply shock, the EIR, and large income effects.

This is intended to be didactic, not ideological, that is not supporting marginalism in general. Note that replacing neo-classical marginal pricing with more general average pricing or prices of production will not change this theory.

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