Economic development with unlimited supplies of energy: causes and consequences of industrial revolutions

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1 General introduction

This dissertation contains three papers, all related as explained in this introduction, all exploring the great unresolved questions surrounding the English Industrial Revolution (EIR). The questions include what happened, why did "it" happen first in England, why did it happen then in history, and what are the consequences? Stepping back to take the long view, this becomes a history of economic growth; in future work, I will use this foundation to illuminate our economic present and possible economic futures.

Economic and other historians have been grappling with these puzzles for a long time; their answers fall along a continuum from New Institutional Economics (some mix of institutions) to almost pure chance. Institutional explanations dominate; I build the case that these explanations are deficient in the sense of not being primarily causal or sufficiently explanatory in the EIR's history. I further make the case that at least the major institutional changes are endogenous to the revolutionary economic changes.

Instead, my major claim is that the EIR was primarily an energy consumption revolution, the English having had the correct economic incentives and historical path to learn how to use steam power to replace muscle power. The contribution is that I attempt the most comprehensive telling of this story that I am aware of.

In fact, I identify two energy revolutions explaining the EIR. The first, converting from wood to coal for industrial and domestic heating purposes, probably happened several times in history. I document a particularly noteworthy instance, that of the iron and steel industry in Sung China. The second, converting from muscle power to steam power happened first in England before engulfing the world.

These are large claims. I take some elements from a small group of scholars that is easily countable. Thus to support my extended claims, I employ several methods including empirical analyses, microeconomic theory, macroeconomic theory, and descriptive narratives from many sources. In general, my method is to apply economic principles to the available data and narratives.

Among my insights, I claim that I can construct a hypothesis of industrial revolutions; this can be tested beyond the cases included in this work. I use basic microeconomics and relevant empirical data (as the data permit) to test the cases of China and England included in this work.

To support the revolutionary growth on the supply side, we must make the case that there was sufficient consumer demand to drive the efforts of the entrepreneurs and inventors. I comment on this in a later section of this introduction.

Before summarizing each paper, I discuss some of the many insights that have occurred during my research; most of these are left to future development.

1.1 Postscripts to the general discussion – insights for future work – interesting questions:

PS1 In evolving to an understanding of the EIR, one of my earliest explorations was the relationship between historical English Gross Domestic Product (GDP) and energy consumption. Having the good fortune of finding a new data series on English energy consumption starting in 1300, I found a very high correlation coefficient between that and GDP; this correlation is 0.998. Statistically, there is no difference between these two data series. This leads me to surmise that this is perhaps the most important fundamental relationship on the supply side. Reflecting on this, it is not that surprising since energy input, no matter the source, is required for all economic, indeed all, activity. And these thoughts contrast fairly dramatically with Robert Solows's famous model in which his capital and labor inputs explained about fifteen percent of the output. Economic output seems tightly tied to thermodynamics, perhaps the truly important connection between economics and physics.

PS2 Related to PS1, energy, again from any source, is non-substitutable. That is, you can change energy sources, and here economic theory describing input substitution works well, but you can not substitute away from energy however measured – Joules, watt-hours, Million Tonnes of Oil Equivalents (MTOE), horsepower, human power, and so forth. Energy is perhaps the only essential input.

PS3 Related to PS2, the theory of value comes to the fore, at least for me. What I claimed above is that it is the energy input that is fundamental to the production process. The source does not matter; a Joule is a Joule whether from a coal lump or a person, purely from the energy input perspective. Given this, what becomes of our theories of value? In particular the labor theory of value, via Smith, Ricardo, and most famously Marx, poses some issues given my claim. And I think these are real, but in order to really understand the implications, we need to categorize the types of labor, then redo the theory of value. Brad deLong offers an interesting taxonomy of the way humans add value:

1. Using their strong (often testosterone-boosted) thigh, back, and shoulder muscles to move things around.
2. Using their nimble fingers to finely-manipulate things.
3. Using their brains as cybernetic-feedback control loops to make sure that the muscles, fingers, and machines do what they are supposed to do.
4. Using their voices, smiles, and frowns to keep us as a group (roughly) on the same page and (roughly) pulling in the same direction.
5. Fully using our brains to think of better ways and more useful ways to do things.

Clearly one, two, and, with increasing automation, three are becoming less efficient for humans to do, so will be substituted away. Four could be jeopardized depending on artificial

intelligence development. Five seems secure at the moment as it involves creativity, but is perhaps also susceptible. So most humans do, and have done, work that can be increasingly easily substituted to various machines. What does that do to the traditional theory of value? I do not have a clear answer; I do know the distribution implications are probably very large.

PS4 In the third paper I explore a simple theory of a very important institution – Industrial Capitalism. I use the basic economic principles of demand and supply. Demand for output has been increasing for a very long time as a function of growing population and living standards, driving the derived demand for productive capital stock upward. There appeared to be no big constraint on supply from the histories. Thus the rise of industrial capitalism in my telling was demand driven, and became sufficiently large that it caused the institution we call Industrial Capitalism. Fundamental economic change caused institutional change. Beyond this example, I have thought considerably about institutions, and suspect that many are similarly endogenous to economic change. Further, institutions are inherently conservative, reactionary, or even repressive as the represent the extant power relationships. Conservative institutions, paraphrasing William Buckley, try to halt the progress of history. Reactionary ones try to turn history back.