

Response to the Referee Report 1

by M. Aykut Attar

First of all, I would like to thank the referee for his/her comments and complimentary words on my paper. I believe the issues raised by the referee are of significance and could be addressed in a revised version. I provide below a discussion of these issues using the structure of the referee's report.

Main Comments

1. *On Alternative Explanations of the Industrial Revolution.* The referee rightly argues that the paper lacks a satisfactory discussion on other mechanisms that provide explanations for the questions of why, where, and when the Industrial Revolution occurred. Other than innovation, economic historians focused earlier on the rise of agriculture before the Industrial Revolution and factors such as capital accumulation, resource endowments, institutions, and the expansion of markets (Hartwell, 1965). Recent works in economic history and economic theory indeed look at how these affect the transition from stagnation to growth in England and elsewhere.

- Even though some economic historians disagree on the exact timing of an agricultural revolution, that the growth of agricultural output in England enabled population to grow fast enough for the advancement of manufacturing industries — through the demand for manufacturing products and the supply of labor — is a common view.

The paper incorporates such a mechanism as the decline of agriculture through productivity growth implies a larger manufacturing sector and, hence, a larger share of entrepreneurs. Not surprisingly, then, a higher value of ψ — increasing the growth rate of agricultural productivity — implies a sooner industrial revolution.

- That capital formation had a large contribution to economic growth during the *first* Industrial Revolution in England is emphasized by Crafts (2004) and Galor and Moav (2004) among others. However, Voigtländer and Voth's (2006) quantitative evidence from a model with capital deepening show that it is the demographic regime with restricted fertility that mainly increased the probability of industrialization in Europe and in England given the central role played by endogenous technological progress. Similarly, Allen (2009) finds that productivity growth — not capital accumulation — was the prime determinant of economic growth during the early stages of the Industrial Revolution.

While extending the model with capital accumulation does not alter the threshold result, it does not, I believe, add much insight to the main message of the paper.

- The role of resource endowments is noted by Pomeranz (2000) with an emphasis on the access to coal reserves in England as one of the very few differences between England and China, but Jones (2010, p. 3) argues “that the connection between industry and the coalfields was actually loose” in England from a geographical point of view.

My paper does not include a natural resource such as coal as a production input, but I think the role of resource endowments is an intriguing aspect of the transition from stagnation to growth.

- Institutional quality is at the center stage at least since North and Thomas (1973), but there does not exist a general consensus here. While the new institutionalist literature emphasizes the Glorious Revolution of 1688 as an important event that secured property rights and that ended the age of absolutism, Clark (2007) shows that the very slowly growing efficiency level was not altered by the Glorious Revolution. Mokyr (2008) further argues that the role of formal institutions within the new institutionalist mode of thinking has been over-emphasized relative to that of informal institutions, social norms, and the cultural beliefs of the political and the technological elite.

The model of my paper remains silent on the role of formal institutions as it analyzes a private ownership economy under perfect competition and free entry. The model, however, incorporates the process of collective discovery as an informal institution, and the exogenous parameter θ is taken as a parameter representing the quality of innovation-promoting institutions.

- The expansion of markets is a cause of the Industrial Revolution — other than agricultural productivity and innovation — over which there is a strong agreement in the literature. Several historians and theorists emphasize the commercial origins of the Industrial Revolution and the rise of national and overseas demand for British products. Two models — those of Desmet and Parente (2012) and Peretto (2013) — indeed show that the intensification of competition across firms basically through the expansion of markets and the firm size gives these firms an incentive to direct resources to inventive activity.

My results on the timing of the Industrial Revolution are in accordance with those of Desmet and Parente (2012) and Peretto (2013) as noted in the paper. Yet, to the best of my knowledge, there does not exist a sufficiently rich dataset that would allow us to determine whether the demand for products or the “supply” of knowledge was more important in triggering the Industrial Revolution. All models with a richer industrial structure than that of the canonical model of Galor and Weil (2000) are still bound to use some aggregative measures of sectoral output and price data.

Missing data and the complexity of unified growth patterns necessarily restrict the researcher’s confidence in proposing sharp statements such as “Factor A caused the Industrial Revolution” and “The Industrial Revolution occurred in England and not in France because of Factor B.” I believe there is no single true model of an industrial revolution that would say the last word on one of the most mysterious events of human history.

My modest purpose — motivated by the prosopographical evidence on inventors and the anecdotal/time-series evidence on patents — is to see whether the dual role of entrepreneurship for useful knowledge enriches our understanding of the transition from stagnation to growth within a simple unified growth framework.

As the referee points out, the threshold result could be obtained within a (static) framework that assumes away or simplifies the unified growth aspects, but I think the model as it is provides a complete story with demographic transition and structural transformation so that the effects of fertility preferences and agricultural technologies on the timing of the Industrial Revolution are almost explicitly analyzed.

2. *On the Role of Science and Scientists.* My dissertation upon which the paper builds upon includes a short discussion section on the role of scientists, and I reproduce that discussion below with minor revisions:

The anecdotal evidence show that professional scientists' direct contribution as inventors to the *first* Industrial Revolution was limited. Also well-known is that British inventors, compared to those of other European nations, were particularly successful in applied sciences that built heavily upon the abstract contributions of, e.g., German and French scientists. That there does not exist a strong causality running from scientific progress to an industrial revolution is also supported by the fact that neither China nor the Islamic civilization, both scientifically superior to Europe at certain eras of antiquity, did realize an earlier industrial revolution. All these, together with the lack of reliable data on the number of scientists and a useful theoretical framework of the economics of science, motivate the model to exclude the role of science and scientists for the process of collective discovery.

A unified growth model that exploits the nexus between discoveries and inventions would ideally incorporate the role of science and scientists. One of the most important actor of the story of technological progress after the first Industrial Revolution is surely the professional scientist, and two issues at least remain unexplored within the unified growth framework: First, why and how the grant-like forms of science patronage dominated the prize-like forms of it starting with the 18th century, a pattern documented by Hanson (1998), is central to the rise of professional scientists. Second, as emphasized by Pumfrey and Dawbarn (2004), science patronage exhibited a historical transition from being mostly ostentatious to being mostly utilitarian, starting first in the 16th century England.

3. *On the Nature of Productivity Growth in Agriculture.* I respectfully disagree with the referee on his/her description of agricultural productivity growth as exogenous since learning-by-doing governs this growth process exactly as in Strulik and Weisdorf (2008). To model agricultural productivity growth via purposeful invention as in the manufacturing sector is worth pursuing, but my earlier attempts were unsuccessful such that I was unable to obtain clear and/or closed-form solutions. I believe the cost of taking this route is remarkably larger than that of exploiting the simplicity of Strulik and Weisdorf's (2008) framework that allows us to provide a satisfactorily rich picture of the co-evolution of agricultural productivity and fertility.

Minor Comments

1. *On the Use of the Concept of Profit.* I agree with the referee on this issue. The correct term for this form of return to entrepreneurs is called inframarginal rent and used by Hellwig and Irmen (2001). I believe a clarification of this issue in a revised version of the paper would be appropriate.
2. *On Equation (11).* The referee correctly identifies an obvious redundancy originating from Equation (11), and I think revising the related parts of the paper would be appropriate.

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