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Habakkuk revisited: A history friendly model of "American and British technology in the nineteenth century"

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Abstract

This paper presents a *History Friendly Model* which addresses the issue of the bifurcation in "technological styles" between US and Britain during the nineteenth century. The model aims at gaining a better understanding of the micro-dynamics that gave rise to different patterns of innovation in the two countries. In particular, we suggest that different demand patterns might be an explanation for the faster diffusion of capital intensive technologies in the US. Simulation results confirm this hypothesis, although only when we jointly control for the role of technological opportunities.

Key Words: Innovation, Demand, History Friendly Model

JEL Classification O3,N0, L6,

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1. Introduction

This paper presents a *History Friendly Model* which addresses the issue of the bifurcation in "technological styles" between US and Britain during the nineteenth century. The model aims at gaining a better understanding of the micro-dynamics that gave rise to different patterns of innovation in the two countries.

A large body of literature dealing with the early phases of industrialisation in the US has been informed by the so-called Rothbarth-Habakkuk thesis (Rothbarth, 1946; Habakkuk, 1962). In their seminal contributions, Habakkuk and Rothbarth pointed to the widespread adoption in the US of relatively capital-intensive techniques (i.e. the so called "American system of manufactures"). According to Habakkuk and Rothbarth, this feature of nineteenth century American technology which aroused so much impression in many contemporary British observers visiting the US and had no counterpart in Britain, was determined by the different resource endowments of the two countries. For most of the nineteenth century, the US was a "land abundant" country. This abundance made the supply of industrial labour scarce and relatively inelastic, generating a systematic upward pressure on industrial wages. This pressure, in turn, induced the adoption of more capital intensive (and labour saving) technologies in the US relatively to those in use in Britain

The connection between factor endowments and different choices of technique can be accounted for by traditional neoclassical theory of production. However the Rothbarth-Habakkuk thesis contends that, besides being more capital intensive, American techniques were, also, in a broad sense, more "progressive". This implication raises the question of why Britain persisted in its use of inferior techniques. In other words, the problem is to account for "[a] systematic bifurcation of the course of technological progress in these two societies whose cultural and scientific heritages held so much in common" (David, 1975, p. 22). As David (1975) has aptly pointed out, the Rothbarth-Habakkuk thesis can be best articulated in an analytical framework in which incremental technical changes are cumulative and localised. In this way initial technical changes tend to be perpetuated over time and countries can move along different technological trajectories, leading to persistent

differential rates of technical progress. David's suggested interpretation appeared to be very appealing, and soon became incorporated in most accounts of nineteenth century industrialisation (Broadberry, 1997). In this paper, we acknowledge the role of path-dependency and we additionally try to show that demand conditions and technological opportunities are a plausible driving of force of the US/UK technological bifurcation. Specifically we focus on the cotton industry which is paradigmatic for the above mentioned bifurcation: indeed, American producers shifted a century ago from the mule to the ring spindles to spin the cotton, while UK producers did not.

2. Main Assumptions

We assume that two main forces droved the micro-dynamics of this story: technology opportunities and demand patterns as also put forward in Habakkuk's account. Indeed, on the one hand, the American system of manufactures generated higher technological opportunities. In Habakkuk's view, in this historical phase, "technical possibilities were richest at the capital-intensive end of the spectrum of techniques" (Habakkuk, 1962, p. 50). Second, English demand was more sophisticated and, therefore, required more customized products: "Another influence on the equipment of American industry was the nature of demand facing American manufacturers. American demand was for uniform standardised types of product. The demand facing English manufacturers was more variegated…." (Habakkuk, 1962, p.123). This hypothesis is consistent with the a body of literature describing the American market as less stratified and more homogeneous (Pine 1993) and with studies of the textile industries pointing to the importance of (technological) flexibility for the wide quality range produced by the Lancashire cotton industry (Saxonhouse and Wright 1984). In the model, we initially explore the effect of each of these two factors individually and, then, we let them interplay. Finally, it is worth noting that our approach regards firms as entities characterised by incremental and localised technical change. This behavioural assumption contributes to lock-in the two countries into two different technological trajectories

3. The Model

The structure of the model and the basic equations derive directly from the new generation of evolutionary models put recently forward by Malerba et Al. (1999, 2001, 2007). The model tries to capture the stylised facts characterizing the evolution of manufacturing sectors in Britain and in the US in the course of the nineteenth century. With respect to previous versions of the model, the main difference is that in the present formulation each firm first chooses a technology, and in a second stage, introduces changes in the product design as a result of this choice. On the contrary, in previous versions, investments in R&D were directly aimed at changing the product design. Secondly, in this version we have a technological frontier that is not given, but (for the US) grows steadily. This allows us to capture the higher technological opportunities generated by the American system of manufacture. The key-elements of the model are the firms, the product they sell and the demand. Firms adopt the same routines in both America and UK and products are developed according to the same production function, only the demand differs, in term of minimal product requirements.

3.1 The product

We follow an approach *á la Lancaster* where the product is considered as a bundle of two attributes: cheapness and degree of customisation. The cheapness is the inverse of price while the degree of customization captures the breadth of variety each product is available. The quality of products´ attributes depend on the technology owned by each firm. Given the initial conditions, we assume that the more investment is directed towards a labour saving technology, the more the output would be cheap and standardised. On the contrary, the labour intensive technology allows the production of a customised, but relatively more expensive good. The product at each period t can be, therefore, depicted in a two dimension space defined by $M1$ (cheapness) and $M2$ (customisation).

The two dimensions of the technology, labour or capital saving, are characterised by the technological frontiers $F1$, $F2$, where $F1$ is label for the labour saving dimension and $F2$ for the capital saving dimension. As mentioned, we assume that the

technological opportunities are higher for capital-saving technical change. Moreover, in some simulation we will we allow technological frontier to expand according to the following specification:

$$F(t) = F(0)[1+\alpha] \tag{1}$$

where α is parameter specifying the speed of change. The shift of the frontier is designed to include in the model progresses in the basic research, in science, and in the organization of production that might affect not only the technology in a given moment of time, but also its full potentiality over time. In other words, this is designed to grasp the essence of the "American system of production" vis á vis the mode of production of the first British Industrial Revolution.

The design improvement ΔM of the product in every period and for each firm depends on the amount of expenditures in R&D, on their allocation between the two technologies for defining the trajectory, on the distance from the technological frontier to grasp decreasing return of R&D, and on the cumulative time the firm has been producing (learning by doing):

$$\Delta M_i = \lambda R_1^{\lambda 1}(F_i - M_i)^{\lambda 2} T^{\lambda 3} \tag{2}$$

i=1 for *cheapness* and *i*=2 for *customization*.

where $\lambda 1, \lambda 2, \lambda 3$ are parameters, *Ri* are R&D expenditure devoted to technology *i*, *Fi* is the technological frontier of technology *i*, and *T* is the number of periods during which a technology has been present on the market.
It is possible to depict the design trajectory of each firm in a two dimensional product space *a la Lancaster.*

[Figure1. about here]

3.2 The Firm

Each firm follows a set of routines common within the industry described as:

Expenditure in R&D: $R_t = \alpha \Pi_t (1-\sigma)$ (3)

Expenditure in Advertising: $A_t = \beta \Pi_t (1-\sigma)$ (4)

Price: $p = (k + \mu)$ (5)

where α β and μ are parameters, *Pt*, the profit of period *t*, *k* the cost of production. Each firm has also to devote an amount of resources to the payback of an initial loan. We assume that the initial loan is the same for all firms. *s* is the fraction of profit used to pay back the initial debt.

Each firm chooses to allocate its resources according to an idiosyncratic technology strategy. This strategy specifies the balance of its investment between labour intensity and capital intensity technology. In the model the strategy is considered as a random choice made in the first period that defines the technological trajectory of the firm. When a firm does not make positive profits it dies.

3.3 The Demand

Consumers consider the two attributes of the product, cheapness and performance, as argument of a *Cobb-Douglas utility function*. Consumers' utility takes a positive value only if the design of their product has reached some minimal thresholds in both its dimensions of cheapness and quality.

$$U = \kappa (M_1 - M_1 \min)^{\gamma 1} (M_2 - M_2 \min)^{\gamma 2} \quad (6)$$

When the minimal thresholds M_i-*min* are reached, firms have a probability to sell their product that depends on the utility associated with their product design:

$$\Pr = \delta U^{\delta 1} (m + \delta_2)^{\delta 3} \quad (7)$$

Where δ, $\delta 1$, $\delta 2$, $\delta 3$ are parameters, *m* is the market share of the firm.

We assume the following crucial difference between US and UK. US buyers accept a smaller product customisation, therefore quality, if the lack of quality is compensated by an increase in cheapness. On the contrary, in England, buyers require higher customisation and are willing to pay a higher price for this. In the model this assumption is reproduced by the different threshold level in the two markets as depicted in Figure 2.

[Figure2. about here]

4. Some empirical evidence

The two tables below give a grasp of the history our model aims to reproduce. The first table depicts that the American manufacturing industry ended up to be in the early 20th century by far more capital intensive than the British one.

The second table, by showing the savings per pound of cotton from using ring spinning, illustrates that there existed only limited advantages for English firms in switching to the new technology. This evidence seems puzzling. On the one hand, the US industry adopted a more capital intensive technology, which was assumed to be more efficient. On the other, observed behavior and statistics, show that the UK manufacture could not profit from the introduction of the ring spinning.

[Table1. about here]

[Table2. about here]

5. The simulation

In the simulations, we explore the effects of different patterns of demand and technological opportunities on the evolution of the technological trajectories in US and UK. Three different scenarios are developed.

In the *Scenario A* we simulate the behaviour of the system when firms are facing different demand conditions, ceteris paribus. As figure 3 pinpointed, pure demand factors are clearly not sufficient to explain the history. The presence of sophisticated demand in the UK market explains the choice of labour saving technology made by British firms. However it does not explain the wide technology gap between US and UK, nor the "extreme" American preference for capital intensive technology.

[Figure3. about here]

The *Scenario B* shows the dynamic of the industry when UK and US are facing different technology conditions, ceteris paribus. A pure technology push explanation is not sufficient either: analogously, it does account for the American tendency towards a capital intensive industry, but not for the British preference for the labour intensive one, nor again for the technology gap.

[Figure 4. about her]

The *Scenario C* depicts different demand condition and different technological condition. In UK the demand shows a higher preference for customisation. In US, a growing frontier for the capital intensive technology captures the larger opportunities provided by the American System of manufactures. The simulation results in this case are consistent with all the stylised facts: UK technology is clearly oriented in labour intensive direction, while the US one in a much more capital intensive one. Moreover, the American industry is clearly more productive given that the trajectory followed and it has higher values for both cheapness and customisation.

[Figure5. about here]

[Table3. about here]

6. Conclusions

Overall, our results have two major implications. First, they point to the need to provide a sound micro-foundation for the patterns of technical change observed at the macro-level and described in terms of productivity and capital/labour ratios. Second, they suggest that 'history friendly' modelling has a potential scope of application that stretches far beyond the analysis of the evolution of particular industrial sectors.

Both implications lay the path for further historical investigations of the determinants of differences in technical practices between the two countries. In particular, the possibility that changing demand patterns may overcome the 'lock in' effect induced by factors endowment has to be addressed since there are a number of historical examples (Saul, 1970), which support the idea that, when they were facing demand conditions similar to the ones prevailing in US, British manufacturers tended to adopt American methods of production.

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Figure 1. Technological frontiers and technological trajectories

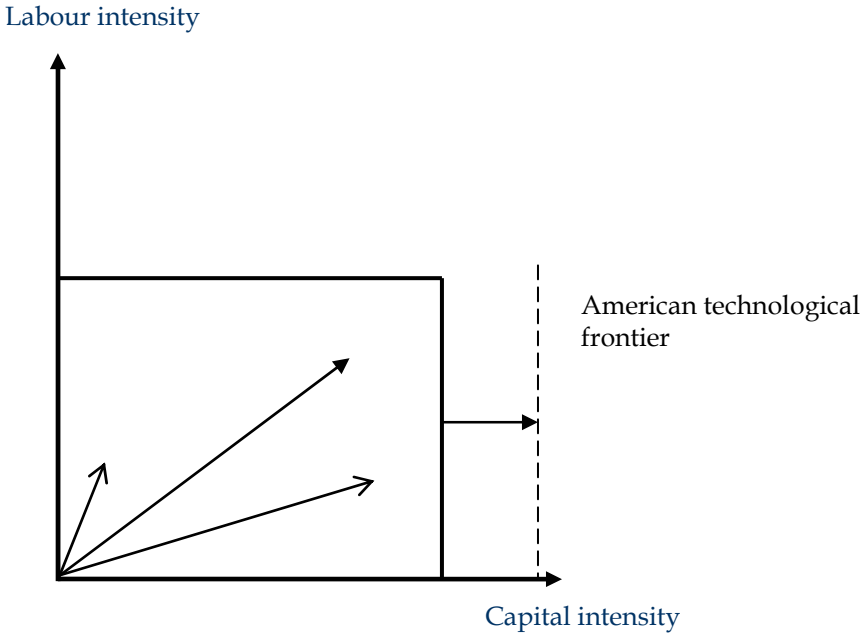

Figure 2.
English and American Market in the Lancasterian product space

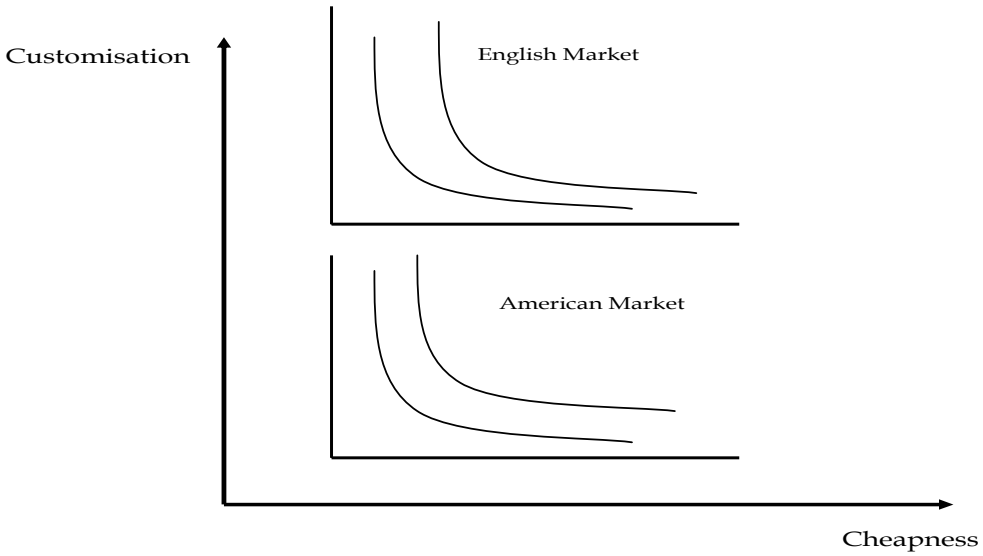

Figure 3. Scenario A

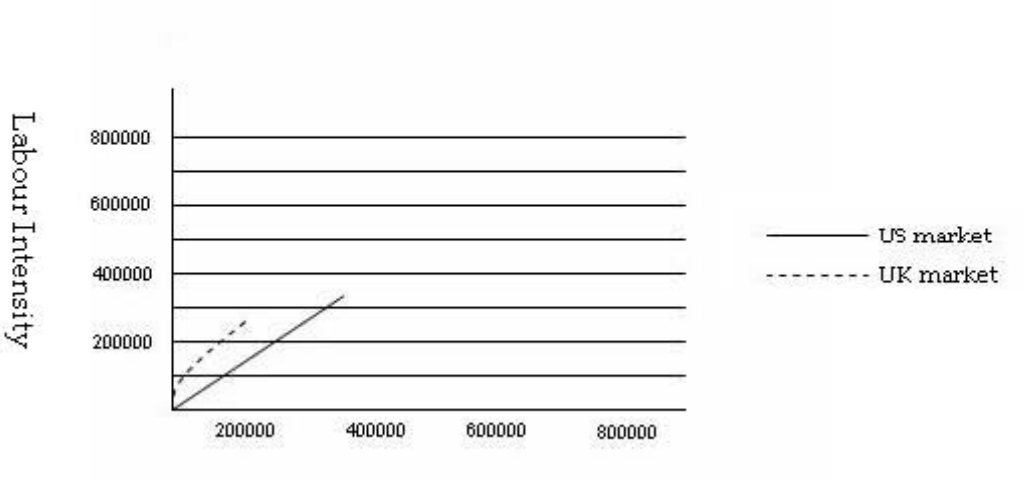

Figure 4. Scenario B

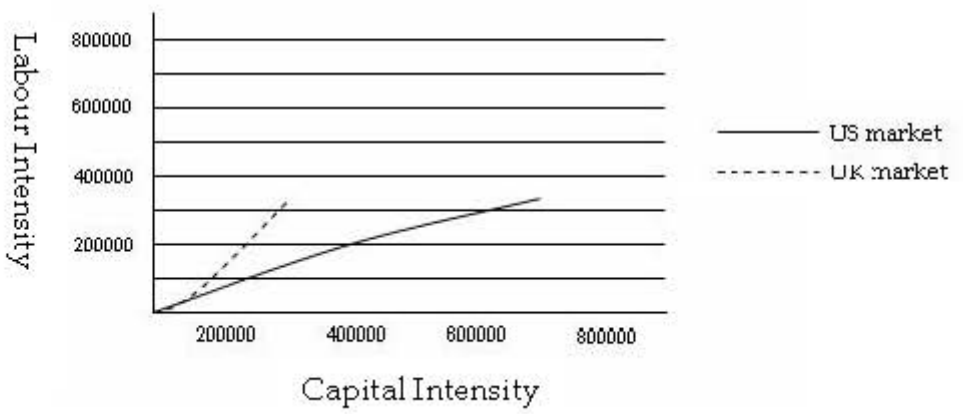

Figure 5. Scenario C

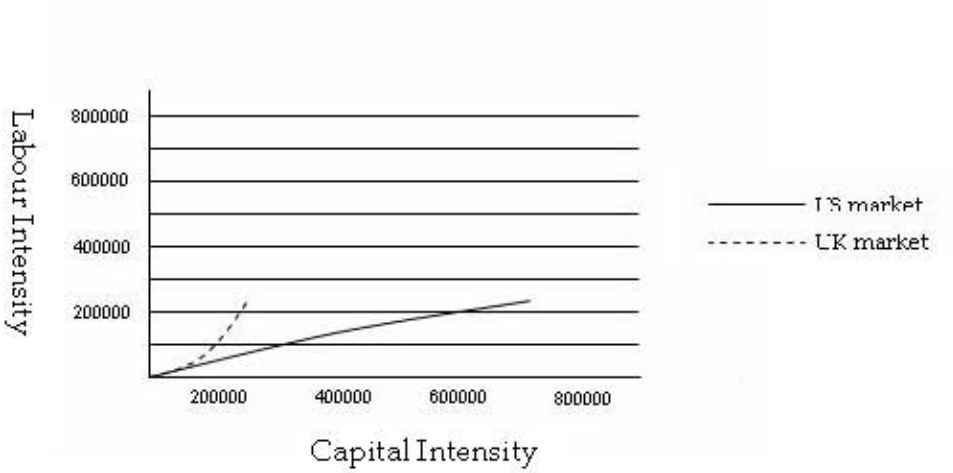

Table 1.
Comparative output per worker and horse-power per worker in manufacturing, 1906-1939 (UK=100).

Country	Year	Output per worker	Horse-Power per worker
US/UK	1909/07	208.5	212.8
	1929/30		195.6
	1939/30		255.8
	1937	208.3	

Source: Adapted from Broadberry (1997: p.109)

Table 2.
Savings in (US cents) per pound of cotton at various counts from using ring spinning instead of mules (US vs. UK before WWI)

Count	40	50	60	70	80	90	100	110	120
UK	1.6	1.7	1.8	1.8	1.8	1.6	1.5	1.2	0.8
US	2.4	2.6	2.9	2.9	3	3	2.9	2.7	2.3

Source: Sandberg (1969)

Table 3. Some crucial parameters.

	Scenario 1		*Scenario2*		*Scenario 3*	
Parameter	US	UK	US	UK	US	UK
Number of firm	80	80	80	80	80	80
Initial technological fontiers	8000-8000	8000-8000	8000-8000	8000-8000	8000-8000	8000-8000
Increase per year capital frontier	0	0	10%	0	10%	0
Increase per year labour frontier	0	0	0	0	0	0
Customisation threshold	400	4000	400	400	400	4000
Cheapness threshold	400	400	400	400	400	400