

Stolpe, Michael

**Book Review — Digitized Version**

[Book Review of] Rosenberg, Nathan: Exploring the black box: technology, economics, and history, Cambridge, Cambridge Univ. Press, 1994

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labor supply, which is questionable, too. Wage and price rigidities have a sound micro-economic foundation and cannot be dismissed as irrational. Taken together, there is some reason to argue that people pay with more unemployment rather than with lower wages at constant employment as stated in the book.

Be that as it may, there is virtually no disagreement with the conclusions by Ehrenberg. They are presented in section 7 which is required reading for anyone interested in this discussion. As is well known there are winners and losers from economic integration. While the losses may fall most heavily on people from certain geographic areas or professional groups, the benefits may be more widespread such as lower prices for consumption. Rather than building barriers by demanding equal pay and labor standards in all countries a better strategy is to help the losers to find another suitable job (I doubt, however, whether the tax on tradable goods mentioned by Ehrenberg is the last word on how to finance that compensation). This does not exclude the application of minimum standards as, for example, laid down by the International Labor Office and agreed upon by many countries: We do not wish to benefit from trade by purchasing goods produced by children and/or inhuman working conditions. However, the question arises about an appropriate strategy. Ehrenberg is right that by requiring those countries to improve their standards before granting them free trade status, may be inferior compared with a combined and simultaneous procedure of improving working conditions and reaping the benefits from international trade. As a second point, we also do not want officials to praise the gains from economic integration on Sunday and to demand full harmonization of labor standards at the prevailing level in the richest country on Monday. The crucial point in the debate is, therefore, to distinguish a legitimate concern about a minimum level of morality from a fear about a loss of international competitiveness for reasons whatsoever. As Ehrenberg rightly notes, there are no simple answers. But his description of the rules in the context of the NAFTA treaty is interesting albeit perhaps not fully transferable to economic integration in Europe.

Taken together, while questioning some details of his analysis, I view Ehrenberg's book a valuable contribution to a lively debate about appropriate responses to the problems of economic integration.

Wolfgang Franz

**Rosenberg, Nathan**, *Exploring the Black Box. Technology, Economics, and History*. Cambridge, New York, Port Chester, Melbourne, Sydney 1994. Cambridge University Press. IX, 274 pp.

Neo-classical economics has usually treated technology as a black box conveniently formalised by a production function. This has made it fairly painless for economists to lose sight of the fact that technological capabilities are largely specific to individual persons, firms, countries and hence of a locally differentiated and cumulative nature, and to assume that technical knowledge was ubiquitous. Despite the paradigmatic dominance of the neo-classical black box, economic historians have not given up reminding the profession that collapsing the technological complexities of production – yielding the vast variety of the innumerable known goods – into a simple mathematical function has often hindered more than helped to understand *historical* processes of economic growth and development. Some, most notably Nobel laureate Douglass North (1990), have pointed to the evolution of *institutions* as an important determinant of location- and time-specific transaction costs, which in turn imply differential productivities and rates of capital accumulation. Nathan Rosenberg, by contrast, has long emphasised the cumulative and path-dependent nature of *technological* change as understood by scientists and engineers.

“Exploring the Black Box”, his most recent book, is a collection of essays on the economic forces which shape the direction and speed of technological change viewed as a unique process in historical time. While the bulk of these essays was previously published in scattered places elsewhere, the book is welcome in bringing together much of the author’s thorough and coherent thinking, looking at the determinants and consequences of technological change from many diverse angles but with a clearly recognisable unifying thread. Chapters are grouped into three parts, dealing with theoretical approaches to technological change, their consequences and policy implications, and a number of pertinent sectoral studies – on the implementation of energy-efficient technologies, on innovation in chemical processing and telecommunications, on the adoption of new technology in the forest products industry, and on the role of university research in the development of scientific instruments. To Rosenberg, the historian, a full understanding of the determinants and consequences of technological change is inconceivable without appreciation of the particular sequence of events and institutions within particular industries. One important insight from his sectoral studies is that the sharp distinction made by neo-classical theory between factor substitution and the growth of technological knowledge is often not applicable to the real world where a large part of firms’ R&D efforts is devoted to learning about new possibilities for factor substitution rather than about possibilities for productivity improvements in the present production process.

That the particular supply and demand forces at work in a particular place and time can indeed provide a rich historical explanation for the direction and character of technological change, is vividly illustrated by Rosenberg’s answer to the intriguing question why “the American system of manufactures” first arose in the United States of the nineteenth century and not elsewhere: Unique demand-side conditions – rapidly growing markets and the widespread acceptance of highly standardised products – as well as supply-side conditions – the abundance of natural resources and the scarcity of labour – initiated the growth of America’s capital-goods sector. This sector’s preoccupation with standardisation and interchangeability, in turn, led to new patterns of specialisation and division of labour, encouraged the transfer of new technology from one industrial application to another and facilitated a degree of technological dynamism and creativity unrivalled in other advanced economies of the second half of the nineteenth century. Moreover, the capital-using path on which America’s industrialisation embarked in the early nineteenth century turned out later to open up particularly rich and ample opportunities for capital-saving innovations. Thus, movements along the path of technological development, initially dictated by peculiar resource conditions, became self-enforcing for the American economy.

This story fits well into the paradigm of path-dependence some of whose strongest exponents, Brian Arthur and Paul David, are faculty fellows of Nathan Rosenberg at Stanford University. The opening chapter of his new book argues that this paradigm provides a more useful explanation than neo-classical orthodoxy of how technological change has been responsive to economic variables in the past, an explanation which, he thinks, can help arrive at a better assessment of the directions of technical change most likely to have a positive payoff in the future. This explanation rejects a simplistic *linear* causality in which science is the exogenous determinant of technology and technology the exogenous determinant of production possibilities. Instead, the relationship between science, technology and the economy is seen as being interactive and dialectic. On the one hand, the stock of scientific knowledge may well be an important determinant of the cost of acquiring information about technological alternatives, which make new points on the production isoquant accessible, albeit without ever making the acquisition of this information costless. Much technological development is therefore incremental, searching for improvements in existing products and processes. On the other hand, not

even science is exogenous, but closely dependent upon progress within the technological realm, because the type of available instrumentation restricts the set of feasible directions for scientific research, and because major technological advances may open up new areas of science. Rosenberg points out that, for instance, research in solid-state physics was dramatically increased after the advent of the transistor in 1948, and that the chemical methods of fabricating semiconductors, introduced with integrated circuits, led to a marked increase of resources devoted to chemical science.

Rosenberg is surely right when he asserts that changing opportunities and needs of technology have come to play a major role in shaping the agenda of science. At the same time, he recognises that scientific breakthroughs may sometimes lead into entirely new technological territory and may, in a sense, liberate the economy from the constraints of the past. But if chance plays such a decisive role, the reader may wonder just how *any* analysis, and be it historical, is supposed to help in assessing the likely payoffs of possible directions of technological change in the future. A bold answer, which Rosenberg however shies away from, would be that there might be certain characteristic patterns because technology might evolve like a self-organising system, in which the local interaction of chance events at the micro level of invention and innovation may lead to the emergence of some kind of regular structure at the macroscopic level of technological change and economic development. Long periods of time, the historian's domain, are the dimension in which macroscopic structure might be easiest to detect. And indeed, from Nikolaj Kondratiev (1926) onwards long cycles in economic activity, whose mere existence remains disputed though, have been linked to technological change by a number of scholars, including many who see themselves in the tradition of Joseph Schumpeter. Rosenberg accepts this hypothesis as an important and challenging question and addresses it comprehensively in a chapter written with Claudio Frischtak, in which they spell out the building blocks that would be needed to establish a complete and consistent causal link from technological change to long waves. But they reject all attempts made so far at formulating such a theory as either incomplete or unconvincing.

An area in which research may have more immediate payoffs, and in which Rosenberg appears more optimistic about answering some of the critical and most urgent questions, is science policy. He envisages the results of this research to enable a kind of road-map of the science/technology landscape to be drawn which should help identify the most important information flows between the two. A promising beginning seems to have been made with the set of comparative country studies on national innovation systems recently edited by Richard Nelson (1993). Turning to policy conclusions, Rosenberg reveals himself to be a true economist, after all, in stressing the importance of creating *incentives* – so for high quality interdisciplinary research and for the rapid diffusion of new technologies, once they come out of development. It lies in the nature of his subject that many questions have had to be left unanswered, but Nathan Rosenberg's explorations prepare the ground well for more research in the future. His new book should prove a valuable read for anybody concerned with technology and economics, not only for historians and economists, but also for policy makers and technology managers.

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Michael Stolpe