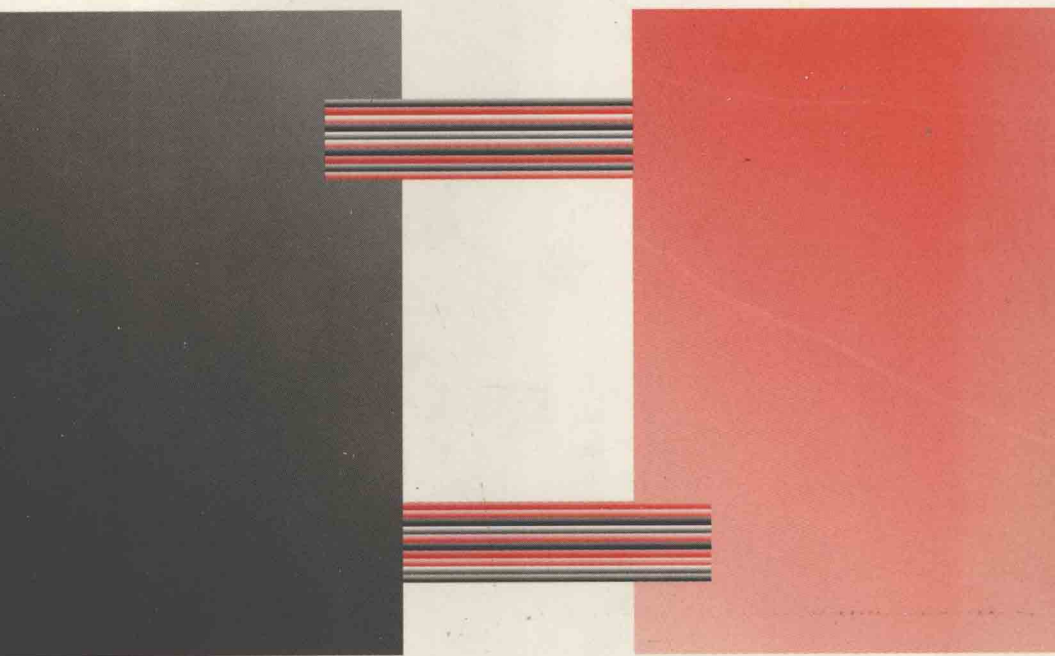


# Trade and Innovation

Theory and Evidence



Katharine Wakelin

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PART I

Technology and Trade Theory



# 1. Introduction

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This book aims to analyse the importance of technology in influencing the trade performance of developed countries. Normally, attempts to explain this objective meet with two distinct reactions. The first reaction, that of non-economists, is that differences in technology between countries seem an *obvious* explanation for differences in trade performance, and that the importance of technology is surely not a controversial issue. The second reaction, that of most economists, is ‘why technology’; how can differences in technology across countries possibly be more than a short-run phenomenon? The reason for the difference in these reactions clearly lies with economic theory which, at least as far as neo-classical trade theory is concerned, has made strong assumptions concerning technology. Neo-classical trade theory has been based on the assumption of identical technological inputs across countries, explicitly ruling out differences in technology as a source of trade. Hence the surprised reaction of most economists to the idea of considering differences in technology as a determinant of trade performance.

## 1.1 WHY TECHNOLOGY AND TRADE?

Despite neglecting the role of technological change in economics in the past, or its characterization as a ‘black box’, there is an increasing interest in understanding the mechanisms of technological change. Technology can be defined as the set of all techniques, or methods for producing a good, available to a firm. At the level of the industry or country technology is thus a collection of firm-specific technology sets (Gomulka, 1990). Technological change is the enlargement of the technology set, which may contain inefficient as well as efficient techniques; while technological progress refers only to the enlargement of the set of efficient techniques. Technology is thus an economic concept relating to techniques which are applied in an economic setting and as such can be separated from knowledge (or science) which attempts to *explain* events rather than

necessarily find applications for them. Clearly the two can be closely linked, and the level of knowledge in a country can have an important impact on technology. This book is primarily concerned with technology rather than knowledge.

The proximity of an idea to an economic application can be used to classify different stages of the innovation process. Scientific research is generally interested in discovering new facts and principles and, particularly in the case of pure research, may have no economic application. Invention is the creation of a new product or production process which may never be adopted, or needs to undergo considerable changes before implementation, and thus has no automatic economic significance. Once an invention is adopted it can be described as an *innovation*, and it is this stage of the process which has most economic significance. While scientific research may be relatively independent of economic imperatives, innovation responds to economic stimuli (often termed the 'demand-pull' view of technological change) as well as to progress made by science ('technology-push'). A fourth crucial phase of the innovation process is the diffusion of innovation from the original innovator to the rest of the economy. The neo-classical approach has considered technology as a 'book of blueprints' in which the new information is codified and easily available; thus diffusion is costless and automatic. When applied to international trade theory this means that the set of techniques is assumed to be common across countries because of the perfect diffusion of information; as a result, all countries share the same production function.

An alternative view of the diffusion process sees technology as being at least partly non-codifiable (that is, tacit) and largely firm specific; this makes the transfer of technology both a costly and a complex process (Nelson, 1992). In this view of technology, innovation can give the innovating firm a specific advantage over its competitors; the level of advantage depends on the degree of codifiability and transferability of the relevant information. When this view of innovation is applied to international trade at an aggregate level, countries may have a technological advantage in some sectors which is not immediately eroded by the diffusion of technology to competing countries, giving a basis for competitive advantage. One approach to trade which is based on this conceptualization of technology as frequently firm, sector and country specific is the neo-Schumpeterian approach, which takes inspiration from the work of Schumpeter (see, for instance, Dosi et al., 1990).

This approach to technology is effective in explaining technological differences between countries, and in particular technological differences between sectors in different countries. The importance of a country's

## *Introduction*

history and institutions in developing its technological profile has led to a number of studies on national systems of innovation (see, for instance, Nelson, 1993); these highlight the diverse technological strengths and weaknesses of different economies. Underlying this aggregate view of the technological strengths of sectors and countries are the firms which produce the innovations. Firms are the units in the economy which undertake most innovations and, on account of the cumulativeness and non-codifiable nature of many innovations, they are also frequently the units which benefit most from innovation. Because of the importance of firms in the innovation process, this book considers not only the role of innovation in affecting sector trade performance for different countries (Part II), but also the role of innovation in affecting firms' trade performance (Part III). The empirical literature has concentrated on the former, with only a few studies considering the role of technology at the firm level. This book aims to provide both a macroeconomic and a microeconomic study of the role of innovation in trade performance.

The role of technology in trade performance is of interest as international trade is of central importance to modern economies. International competitiveness is one of the issues which most dominates the economic agenda, and there are considerable institutional attempts to regulate international trade flows. These fall into three main groups. The first is the commitment to free trade, and the international and multilateral attempt to reduce restrictions on the free movement of goods internationally, through the General Agreement on Tariffs and Trade (GATT). The second is the integration of countries into customs unions and free trade areas, such as the European Union, and the North American Free Trade Agreement (NAFTA), which are based on the perceived benefits of free trade between a limited number of countries. The third is the area of domestic competition policy, which is increasingly becoming an arena for international dispute, and its regulation is part of the process of integration. Domestic competition policy relates to industry subsidies, the control of national wages and science and technology policy, which are all designed to protect and sustain national competitiveness. These three areas of trade policy – the control of tariffs, the creation of customs unions (and free trade areas), and the international regulation of national competition policy – remain some of the key issues for economic policy, and some of the most contentious. International trade, and international competitiveness in general, are seen as important components of the national economy which can affect domestic welfare and growth.

The significance attached to trade by economic policy makers, is due to the increasing openness of industrialized countries since the Second World

War. Advanced countries export a much higher proportion of their output than in early periods and, as a result, countries are increasingly integrated internationally, with events in foreign markets affecting the domestic market in most countries. The basis of this change has been spectacular improvements in communication which allow contact to be made easily across national and continental borders. The result of this increased integration is that small, and even medium-sized countries, are reliant on international markets for a large part of their economic transactions; and even large economies – such as the United States – are integrated with foreign markets. As a result, understanding the determinants of international competitiveness is of key importance to national economies.

The countries considered in the macroeconomic part of this book are all advanced industrialized countries at similar levels of development, and with similar real incomes per capita. However, despite this similarity in the level of income and development, the OECD countries have experienced different growth rates. One explanation for these growth differences is their varying levels of innovation, and patterns of specialization. The main hypothesis of the macroeconomic section is that technology gaps exist even between advanced countries which have similar income levels and are highly integrated. That technology gaps can persist among countries trading freely and with integrated economic systems, such as the European Union countries, indicates some salient characteristics of technology. Most importantly, it indicates that despite sharing a common scientific base, countries can still have national systems of innovation which are unique, and which reflect past experience. One implication is that economic integration and trade do not bring with them the automatic diffusion of technology; rather that technology is frequently localized, and cannot as a result be characterized as freely transferable internationally. Technological advantages remain specific, and technology gaps can be maintained between countries. The microeconomic section of the book considers the same issue at the firm level: whether differences in innovation among firms can help to explain differences in their export performance.

## 1.2 AN OVERVIEW

This book aims to evaluate the impact of differences in innovation on trade performance from an empirical perspective. The approach is consistent with new international economics and with a neo-Schumpeterian perspective, in that both predict that differences in innovation will play a central role in determining international trade patterns. However, the treatment of

technology, and in particular the emphasis on the firm in Part III, is consistent with the neo-Schumpeterian view of technological change outlined in Chapters 2 and 6. The book combines both a macroeconomic and a microeconomic perspective on the relationship between trade and innovation.

Considerable attention is paid to the firm-, sector- and country-specific characteristics which influence the relationship between trade and innovation. The measurement of innovation, including the selection of the most appropriate proxy for technological change, and the influence of the choice of proxy on the results of the analysis, is also treated in some detail. A number of different proxies for innovation are considered, including both patent-based and R&D expenditure-based proxies, and actual counts of both innovations used and innovations produced at a sectoral level in the UK are included in the analysis.

The book is divided into four main parts. The first examines the treatment of technology in international trade theory. The development of technology in theories of trade is considered, not just in those theories which have concentrated on technology as the major determinant of trade (the so-called neo-technology theories of trade), but also neo-classical and market structure explanations for trade.

Chapter 3 of Part I follows on from the review of the treatment of technology to discuss some common features of empirical work relating differences in innovation to trade. The empirical literature is organized around three main themes: the use of a dynamic or static model of trade; whether the relationship is considered across sectors for one country or across countries for each sector; and the choice of the innovation proxy. The methodological implications of these choices are also discussed. This framework is chosen as few empirical studies (with the exception of tests of the Heckscher–Ohlin–Samuelson model) are precise tests of existing theories of trade. Rather, a number of determinants of trade are normally considered, including technology; thus attempts to classify the literature on the basis of the existing theories can be highly misleading, and a classification based on the features of the empirical model used is preferred.

Part II considers the impact of innovation on inter-country trade. It is divided into two chapters. The first, Chapter 4, concentrates on trade among four European countries. It considers the impact of differences in innovation on bilateral trade, with an extension to those countries' trade with all European countries. Simple correlations are made between bilateral differences in innovation (proxied by patents) and bilateral trade performance. The objective is to assess the extent of technology gaps between these four advanced European Union countries, both on a bilateral

basis for each pair of countries, and multilaterally within Europe. The relationship is also considered for each sector across the bilateral trade flows, as large variations in the relationship are expected between European countries. Particular attention is given to how the relationship varies according to the countries and sectors involved. By considering only correlations between technology gaps and trade performance, the analysis abstracts from other determinants of trade. This reduces the explanatory power of the relationship, as differences in innovation are not expected to explain all the variation in bilateral trade performance; nevertheless it does isolate those sectors and countries for which the relationship is most important. Chapter 4 can be considered a preliminary analysis, and relates closely to Chapter 5; the latter considers the same relationship but with a more complete specification, including additional explanatory variables, and for a larger number of countries. Chapter 4 has the merit of covering a wide range of industries, including very-high-technology industries, medium-technology industries and resource-based industries.

Chapter 5 examines the relationship between trade and innovation for nine OECD countries. Additional determinants of trade performance are included as well as innovation. As in Chapter 4, the relationship is considered on a bilateral basis, and differences in innovation across countries are taken as one of the explanatory variables. Initially, two proxies for innovation are used, so variations in the relationship due to the choice of proxy can be observed; one is based on R&D expenditure and the other on patents taken out in the US. Chapter 5 also investigates how the relationship varies over sectors and countries. The importance of variations in the relationship either by country or by sector reflects whether it is sector characteristics, such as the level of technological opportunity in the sector, or country characteristics, such as national institutions, which most influence the role of technology. A final section uses actual counts of innovation in the UK as explanatory variables for the bilateral trade of the UK with the other countries. In addition, the ratio of innovations produced and used in each sector is used to classify the sectors into net users and net producers of innovations; the relationship between innovation and trade performance is considered separately for each group of sectors.

The third part of the book extends the analysis of the impact of technology to the international performance of firms. The last section considers the impact of innovation on trade at the level of the firm for a group of UK firms. The microeconomic perspective is taken to be particularly appropriate as technological accumulation occurs primarily at the level of the firm. The innovation history of each firm is used to characterize it as either an innovator or a non-innovator, based on a survey

of innovations in the UK. The characteristics of the two groups of firms are then considered; a number of key features such as the propensity to export and the size of the firm are found to vary according to whether firms are innovators or non-innovators. Innovation is considered to give a firm a specific competitive advantage which improves its performance, including its performance on foreign markets, and leads to greater exports; in addition it may also increase the probability of a firm exporting. In order to test these propositions an empirical model of the determinants of export behaviour is set up, including both firm-specific characteristics and also characteristics of the sector in which the firm is located. Particular emphasis is placed on the innovation characteristics of both the firm and the sector. The relationship is tested both for the innovating and non-innovating firms grouped together, and for them separated, to see if the determinants of export behaviour vary over the two groups.

This microeconomic perspective on trade performance is unusual within the literature on international trade. It has been widely applied in the study of foreign direct investment by multinational companies (MNCs); firm-specific characteristics are clearly seen as one of the main causes of such investment. This part of the book aims to extend the analysis of the importance of firm-specific characteristics to explaining *export* behaviour. This is partly due to the emphasis on technology as a source of trade; innovation leads to a firm-specific advantage which can also improve a firm's performance on export markets as well as acting as an incentive to foreign direct investment. In addition, the influence of innovation can be divided into two components: that specific to the firm; and that which results from being in an innovative sector. The relative importance of these two factors can be assessed for the innovating and non-innovating firms.

Finally, Part IV presents the conclusions of the analysis. As separate conclusions are included in each chapter, the last part aims to give a broader view of the relationships between the results of all the chapters, and the implications they have for the themes discussed throughout this book. In addition, the policy implications and the limitations of the analysis are discussed.

## 2. The Treatment of Technology

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Attempts to include technological change as a factor affecting international patterns of specialization have involved either adaptations of the neo-classical approach, or the adoption of a different approach to international trade which explicitly considers technology as of central importance. However, empirical attempts to explain patterns of specialization have frequently been characterized by an *ad hoc* approach, combining a number of different determinants of trade taken from different theoretical frameworks. This chapter delineates the principal theoretical approaches for including technology in trade models. Some readers may find the differences among theories arbitrary – for instance, between the neo-endowment and neo-technology approaches – but each has a different theoretical context which affects the way technology is perceived.

The first part of the chapter presents an overview of the Heckscher–Ohlin–Samuelson model and developments from it, as well as some empirical work inspired by it. The second section covers the so-called neo-technology theories of trade, or those theories which have given technology a central role in explaining trade patterns. Some empirical work in this area is also reviewed. Following on from the technology theories of trade, the more recent market structure approach is outlined in Section 3. Finally, the recent developments introducing endogenous technology into neo-classical models of trade leading to dynamic comparative advantage are briefly considered in Section 4.

### 2.1 THE HECKSCHER–OHLIN–SAMUELSON AND NEO-ENDOWMENT MODELS OF TRADE

The classical theory of international trade focused on explanations for the pattern of trade: which goods countries trade and with whom, and with the normative implications for free trade. The basis of classical theory is David Ricardo's theory of comparative advantage, which states that countries will export those goods they can produce with lowest relative costs (and therefore

prices) under autarky. The contribution of this theory is that, in a two-good two-country model in which one country has an absolute advantage in producing both goods, there still exist gains from trade for both countries. Ricardo saw relative labour productivity as determining differences in costs and prices and providing the basis for comparative advantage. Neo-classical theory subsequently considered the *determinants* of comparative advantage and the resulting prices of goods and factors. The Heckscher–Ohlin–Samuelson (H–O–S) theory derives the determinants of comparative advantage in a two-good, two-factor, two-country model, predicting that a country will export those goods which use most intensively the country's more abundant factor of production. The two factors considered were capital and labour and thus the exports of a country should reflect their relative endowments of capital or labour by being either relatively capital or relatively labour intensive. In order to arrive at that prediction the theory imposes a number of limiting assumptions. The first applies to the production function, which is assumed to be static and common to all countries, ruling out technological advantage as a motivation for trade within this framework. There is also assumed to be no factor intensity reversal across countries, so that each country uses the same capital to labour ratio in the production of a certain good. The other assumptions are perfect competition and the complete mobility of factors within a country but their complete immobility between countries. Demand is also assumed to be identical across countries, with consumers maximizing an identical homothetic utility function.

The mainstream of international trade theory, then, concentrated on refining this approach (for instance the work of Vanek, generalizing the theory to more than two factors of production; for more recent extensions, see Deardorff, 1994); and the empirical testing of the theory, inspired by the work of Leontief (1953). Leontief aimed to test the factor proportions theory for the US economy, and found the famous, and at the time deeply disturbing result, that the US, assumed to be the most capital-rich country in the world, was exporting more labour-intensive goods than it was importing.<sup>1</sup> This became known as the Leontief paradox. The apparent lack of empirical support for the factor proportions theory led to a number of new empirical tests and refinements, and to a theoretical search for alternative explanations for the trade pattern, one strand of which was to consider technological differences as a source of trade. A more recent test of the H–O–S theory (Bowen et al. 1987) found almost no empirical support for it.

As well as considering alternative explanations for trade, the original factor proportions hypothesis was extended by subdividing the factors of production included in the model. The most important development in this field was to divide labour into skilled labour (human capital) and unskilled labour. This