Technical change and international trade

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Introduction

In contrast to many other fields of economic theory, international trade theory has traditionally kept the importance of technical change in explaining international trade flows or the international ‘competitiveness’ of a country or an industry at the centre of much economic debate. This can be explained to a large extent by the almost unique influence of ‘classical’ thinking in the area of international trade, with many contemporary trade theorists even expressing today, and particularly with regard to the technology assumption, strong doubts as to the actual contribution of ‘neo-classical’ thinking.

The fact that ‘pure’ neo-classical trade theory is still so prominent in international trade textbooks and is still held in such esteem by policymakers (at least until recently) has indeed little to do with the way that ‘factor endowments’ (pure Heckscher–Ohlin–Samuelson) trade theory explains international trade flows. Its value as a descriptive theory—i.e. national differences in endowments of productive factors form the basis for trade—is regarded as very limited.

Like so many other fields of economic analysis, the ‘strength’ of the pure orthodox theoretical framework lies primarily in the relatively straightforward normative implications—in terms of the gains from trade for both trading partners, as well as international factor price equalization—which can be built around the model. The fact that in order to do so it has to rely on a set of extreme ‘heroic’ assumptions is then generally justified in terms of cost–benefit analysis: the insights gained by such a simple but complete trade/welfare picture outstrip by far the disadvantages of more realistic but more complex and less clear analyses.

Such a view requires, however, first that a ‘reasonably accurate’ explanation is offered for the main interdependencies identified by the theory, and, second, that the distortions and imperfections of the real world lead only to minor or ‘short-lived’ aberrations with relatively little consequence for the normative or policy conclusions of the theory. In the case of ‘orthodox’ trade theory and rather uniquely amongst nearly all fields of
economic inquiry there has been growing recognition from all sides that both conditions do not hold.

Nowhere is this more clearly illustrated than in the seminal review which Hufbauer (1970) presented nearly twenty years ago on the emerging and growing evidence and support in favour of the so-called 'neo-technology' accounts of international trade flows. In interpreting his neo-technology results, Hufbauer, himself author of one of the most detailed technology 'gap' trade studies on synthetic materials (1966), remained, if anything, rather schizophrenic. His 'neo-technology' results, while powerful in explaining the actual trade flows and admittedly closer to the real world, represented an approach which, in Hufbauer's words, was not 'geared to answering the traditional questions of economic inquiry'. And Hufbauer added with some irony: 'It can as yet offer little to compare with Samuelson's magnificent (if misleading) factor-price equalisation theorem' (Hufbauer, 1970, p. 192).

While Hufbauer's contribution was exceptional in its frankness, it was in no way exceptional in bringing out the dilemma between relevance and consistency with a general and established theoretical framework which has characterized the analysis of technical change in economic theory.

Some authors privilege the first criterion (relevance) and find in the evidence on technological change a powerful challenge pushing toward the search for a radically different theory. As Rosenberg puts it,

in a world where rapid technological change is taking place we may need an analytical apparatus which focuses in a central way upon the process of technological change itself, rather than treating it simply as an exogenous force which leads to disturbances from equilibrium situations and thereby sets in motion an adjustment process leading to a new equilibrium [Rosenberg, 1970, pp. 69–70].

Conversely, other economists stress as a necessary condition for the theoretical consideration of the phenomena related to technological change precisely their tractability within the traditional model or simply consider the absence of any alternative as a sufficient condition for their neglect. In Bhagwati's words,

the 'realistic' phenomena . . . such as the development of new technologies in consumption and production involve essentially phenomena of imperfect competition for which, despite Chamberlin and Joan Robinson, we still do not have today any serious theories of general equilibrium . . . Unless therefore we have a new powerful theoretic system . . . we cannot really hope to make a dent in the traditional frame of analysis [Bhagwati, 1970, p. 23].

These two positions illustrate in many ways also two archetypes of scientific strategies, the first focusing on the search for alternative models conforming more to reality and the second pursuing a gradual and progressive incorporation of an increasing number of phenomena into modified forms of neo-classical general equilibrium analysis. It may be useful to use such theoretical benchmarks to review a highly selected literature which presents a high variance in its 'degree of orthodoxy', scope
and realism of the assumptions. We shall in this short review start from what could be called an 'incrementalist' analysis of technology-related phenomena broadly along the lines of the neo-classical approach.

The 'pure' theory: neo-classical extensions and the revisionists

Consider first the neo-classical 'pure' theory of trade in its simplest textbook form. There are generally four fundamental assumptions:

(i) **On technology.** Differences in technologies can be adequately represented by production functions. The latter are assumed to represent the real world, are well behaved, continuous, differentiable, exhibit non-increasing returns to scale, etc. Moreover, they are assumed identical across countries.

(ii) **On behaviours.** Perfect competition prevails throughout. Agents are maximisers under budget constraints.

(iii) **On demand.** Identical tastes across countries and well-behaved utility functions.

(iv) **On adjustment mechanism.** Adjustments are such as to guarantee **ex hypothesi** the clearing of all commodity and factor markets.

These assumptions lead to the following subsidiary assumption: hypotheses (i)-(iv) offer a reasonably accurate description of the prevailing 'state of the world' and the main interdependencies in the international arena, so that any possible distortions or imperfections of the real world lead only to minor or 'short-lived' aberrations with relatively little consequence for the interpretative and normative conclusions of the theory.

In its simplest form, the 'pure' theory of international trade then goes on to prove some of the most 'classic' theorems of economic theory: on relative specialisation determined by relative factor endowments (Heckscher–Ohlin–Samuelson theorem), on factor-price equalisation, and the theorem of comparative statics on the effects of changing prices on factors' returns (Stolper–Samuelson theorem) and of changing endowments upon commodity outputs (Rybczynski theorem).

We will not consider here the developments and refinements of all four above hypotheses, but will limit our review to some of those contributions which do not entirely subscribe to the derived hypothesis that distortions are short-lived, and have tried therefore to modify some of the assumptions (i)-(iv). Typically, the scientific strategy is to hold the rest as true and work out the implications of the additional (more 'realistic') hypothesis. Assumption (iv) remains, however, the core proposition which is generally kept untouched, since the entire model, irrespective of how it is precisely defined, needs a link of some kind between relative scarcities and relative prices.

One way of relaxing the simplest technological assumptions has been by allowing production functions to be different between countries. Jones
(1970) analyses some of the implications: factor price equalisation does not
occur any longer, 'differential rates of technical differences between coun-
tries come to dominate the determination of comparative advantages'
p. 84), but the Heckscher-Ohlin theorem on specialisation still applies in
a modified form. Berglas and Jones (1977) embody in their model a
mechanism of learning-by-doing characterised by 'local learning'
(Atkinson and Stiglitz, 1969) on the techniques effectively in use. Findlay
(1978) develops a steady-state dynamic model including technology
transfers between an 'advanced' country and a 'backward' one. Chipman
(1970) considers the case of moving production functions whereby tech-
nical progress is itself endogenous along Kennedy-von Weizsäcker-
Samuelson lines (cf. Kennedy, 1964; von Weizsäcker, 1965; Samuelson,
1965). Purvis (1972) present a model with international technological
differences and capital mobility, illustrating that in this case, contrary to
the standard model, factor mobility and trade may be complementary. The
issue of capital mobility is also considered by Ferguson (1978) and Jones
(1980): interestingly, the patterns of trade turn out to be essentially deter-
mined by technology gaps and relative labour costs.

Another way of relaxing the standard assumption with regard to the
production function is by introducing economies of scale. Since the analysis
of the latter must be generally associated with behavioural assumptions
different from the pure competitive model, one may consider these two
variations on the standard model together. First, as Drèze (1960, 1961)
and Ohlin (1933) himself, already fifty years ago, pointed out, economies
of scale taken on their own can be an explanatory variable of trade
patterns. Second, from a more normative point of view, they may well
influence the welfare effects of trade so that a country may even lose from
trade, as suggested originally by Graham (1923).

More recently several interesting theoretical developments have been
produced in this area (see Dixit and Norman, 1980; Chapter 9). Krugman
(1979, 1984a, 1982a) has explored the conditions under which Graham's
arguments hold: they depend on the nature of the increasing returns
(which are either 'national' or 'international') and the pattern of change in
relative prices due to the transition from autarky to trade. Imperfect
competition due to increasing returns may imply gains from trade for both
trading partners (cf. Melvin, 1969, and Krugman, 1979a) but may also
imply losses (cf. Kemp, 1969). In the case of 'imperfect competition' a
large number of conclusions emerge which may be diametrically in conflict
with the standard Heckscher-Ohlin-Samuelson model: for example,
factor prices will not be equalised, but, on the contrary, the price of the
factor used intensively in the production of the export good may actually
be high in each country (cf. Markusen and Melvin, 1980, p. 3). Similarly,
factor mobility instead of substituting for trade (trade in factors as opposed
to trade in commodities), as in the standard model, will be complementary
to trade, with each country achieving an equilibrium where it is well
dowered with the factor used intensively in the production of its export
good. As Markusen and Melvin (1980) note: 'In the Heckscher–Ohlin model this is, of course, the basis for trade whereas in the present model it is the result of trade' (p. 3).

In general, as shown by Markusen and Melvin (1984), sufficient conditions for the gains-from-trade theorems to hold are (i) on the behavioural side, marginal pricing, and (ii) on the technological side, the convexity of the production possibility sets.

The analysis of differentiated products, on the other hand, has led to attempts at synthesis between theories of monopolistic competition, intra- and inter-industry trade. Differentiation is supposed to come from a demand for a variety of product characteristics (cf. Barker, 1977; Dixit and Stiglitz, 1977; Krugman, 1979, 1980, 1981) or from different combinations of some fundamental attributes (cf. Lancaster, 1979) embodied in each product. Thus whereas intra-industry trade (see Grubel and Lloyd, 1975) is explained on the grounds of monopolistic competition, the explanation for the inter-industry trade flows will be left to the traditional Heckscher–Ohlin model. These models predict that intra-industry trade will be highest between similar countries in terms of per capita income and patterns of demand (Linder, 1961), whereas inter-industry flows will be more important the greater the difference between countries in terms of their 'endowments'. An alternative (Ricardian) model of intra-industry trade is provided by Petri (1980), where intra-industrial specialisation for any given pattern of demand is determined by relative labour productivities and cost conditions within sector-specific and country-specific structures of production.

Another line of analysis of those market structures different from pure competition has been pioneered by Caves (1971, 1974) in an attempt to link instruments and concepts of industrial organisation (multinational corporations, oligopolistic competition, strategic behaviours) with a general equilibrium trade model. A growing literature on industrial organisation and international trade has emerged since. While some of the results can be formally represented in terms of the traditional model with specific factors, this line of enquiry has more clearly drawn attention to the significance of the link between industrial structures and trade flows (given whatever 'endowments') and to a different adjustment mechanism (international capital mobility in the form of multinational investment rather than intra-national, inter-sectoral mobility). This line of analysis allows therefore, at least in principle, the consideration of country-specific variables, both institutional and economic in nature which as such represent absolute advantages/disadvantages and hence also incentives/obstacles to the location of international capital (see Jones, 1980).

Under the broad heading of 'industrial organisation and international trade', one must also mention parts of the vast literature on the origins and effects of multinational corporations. Some of the studies are quite far in spirit and construction from the neo-classical assumptions listed above (e.g. Hymer, 1976): technological differences between companies and
countries, country-specific absolute advantages and high degrees of 'imperfection' of markets in general and the market for technology in particular are implicit from the start. These features of the world are indeed the necessary structural conditions for the existence of multinationals. Other interpretative models try to incorporate also some neo-classical elements. This appears to be the case of Dunning's 'eclectic theory' (see Dunning, 1977, 1981a, 1981b; Buckley and Casson, 1976) whereby Heckscher–Ohlin mechanisms of adjustment in prices, quantities, and relative specialisation are considered as one of the processes at work, whose relative importance depends on the sectors, the degree of development of the countries, and the nature of the technology. Finally, other interpretations—such as Rugman (1980)—try to reconcile the existence of multinationals, intra-firm trade, etc., with traditional analysis. Rugman recognises the widespread existence of 'imperfections' (and thus the limited validity of assumptions (i) and (ii) above). However, he assumes that companies face and overcome these imperfections by internalising the relevant transactions. Therefore multinationals become some kind of 'second-best approximation' to the working of the standard model.

None of these theories has been thoroughly formalised. It is safe to say though that all of them, to different degrees, lead to conclusions at variance with the canonic model: factor prices are not generally equalised, there are oligopolistic rents, trade patterns do not depend only on countries' endowments, the degrees and forms of market 'imperfections' become a determinant on their own of productive locations and trade.

Some models adopt 'Ricardian' hypotheses on technology—with coefficients of production fixed and different between countries—while generally retaining general equilibrium assumptions on prices, determined through a market clearing process. Dornbusch, Fisher and Samuelson (1977) present a two-country Ricardian model with a 'continuum' of commodities and the patterns of specialisation determined by relative wages and relative productivities. Wilson (1980) extends the model to many countries and non-homotetic demand schedules. Jones (1979) considers the conditions under which technical progress may produce 'immiserizing growth' for either of the trade partners.

A simple but illuminating picture of the technology–trade relationship emerges from Krugman's North–South trade model (1979a, 1982). Starting from an innovative North and a non-innovative South, where the North's innovations take the form only of new products produced immediately in the North, but only after a lag in the South, Krugman (1979a) shows how new industries have to emerge constantly in the North in order to maintain its living standards since the new industries decline and disappear sooner or later in the face of low-wage competition from the South. In Krugman's model, this is because the North's wages reflect the rent on the North's monopoly of new technology: 'This monopoly is continually eroded by technological borrowing and must be maintained by constant innovation of new products. Like Alice and the Red Queen,
developed region must keep running to stay in the same place' (Krugman, 1979a, p. 262). In other words, while the North will be able to achieve some 'moving equilibrium' through a large enough rate of innovation, acceleration of technology transfer will narrow the wage differentials between North and South and might even lead to an absolute decline in living standards in the North. The most interesting aspect of Krugman’s model is, maybe paradoxically, the set of simplistic and, from a traditional trade point of view, totally 'unrealistic' assumptions behind the model: there are no differences in factor endowments, because there is only one factor of production (labour); and all goods, old and new, are produced with the same cost function, leaving no room for differences in labour productivity. Neither neo-classical nor Ricardian trade explanations are relevant, there is no fixed pattern of trade, but trade is determined by a continuing process of innovation in the North and technology transfer to the South. Yet despite these simplifications, some of the conclusions, which emerge from the model are very appealing, not least because, as Krugman observes: 'The picture of trade seems in some ways more like that of businessmen or economic historians than that of trade theorists' (Krugman, 1979a, p. 265).

It is obviously very difficult to provide a synthetic assessment of these quite heterogeneous streams of literature, characterised as they are by very different directions and degrees of 'revisionism'. Three general conclusions, however, may be drawn.

First, there is probably little disagreement, even among neo-classical trade theorists, about the inadequacy of the 'canonic' factor proportions theory to explain by itself international trade flows. As Krugman (1979c) puts it: '.. . . . casual observation seems to militate against a simple factor proportions theory. The emphasis on factor proportions in international trade is . . . not the result of an empirical judgement' (p. 14).

Second, most of the studies we reviewed implicitly highlight the lack of robustness of the major Heckscher-Ohlin-Samuelson results in terms of both predictions and welfare implications. Relaxation of the least realistic assumptions (i.e. perfect competition, constant returns to scale, factor immobility, immediate and free diffusion of technology, existence of well-behaved production functions) leads, generally speaking, to indeterminate predictions in relation to the direction and volume of trade. Moreover, the factor-price equalisation theorem does not generally follow. In terms of welfare implications, depending on which assumption is relaxed, conclusions on the 'gains from trade' are sometimes in accordance and sometimes at variance with the orthodox model.

Third, and from our perspective of more direct interest, quite interesting results sometimes emerge, despite the continuing presence of highly restrictive assumptions. This set of conclusions could prove to be even more important when placed in an alternative theoretical framework: for example, the role of technology gaps, country-specific absolute advantages and different forms of industrial organisation; the importance of
economies of scale and various types of learning; the absence of any general tendency towards factor-price equalisation.

It was already mentioned at the beginning of this survey that a core assumption shared by most of the models reviewed so far is a scarcity link between factors, commodities and prices, irrespective of the particular hypotheses on technology, forms of competition, etc. In this sense, the contributions reviewed above share all the points of strength and weakness of general equilibrium analysis. The strength, in our view, relates to the capability of handling with a simple and general theoretical device the question of interdependence among national and international markets. Not surprisingly, the main question addressed by the standard Heckscher–Ohlin–Samuelson theory and by most of its 'revisionist' developments concerns the patterns of specialisation of each country in relation to some country-specific characteristics.

The other side of this coin is that such analyses, undertaken in terms of equilibrium positions, take as given that (i) there are adjustment mechanisms which generally lead to such equilibria, and (ii) that these mechanisms based on price/quantity adjustments—as in the standard Walrasian model—lead to the clearing of all markets. Both points are difficult to accept on either theoretical or empirical grounds. The difficulties in accounting for the adjustment processes in the standard general equilibrium framework when neither the fantastic 'auctioneer' nor a complete set of contingency markets exist (see Hahn, 1984; Leijonhufvud, 1981) are well known and discussed at greater length in some of the other contributions to this volume. There is, however, no reason to believe that such adjustment processes are any easier in the open economy case.

On more empirical grounds, it is difficult to believe that relative prices are explained by relative scarcities in a world generally characterized by various forms of static and dynamic economies of scale, continuous technical progress, national economies often characterised by some degrees of unutilised labour or labour and capital.

The very formulation of the standard model in its 'timeless' form becomes even harder to accept whenever one of the factors of endowment—capital—is as such a set of reproducible (and heterogeneous) commodities. The question has been discussed in a 'capital controversy',\textsuperscript{10} with many points in common with the famous 'Cambridge Debate' on capital theory, focusing on the problems ranging from the heterogeneity of capital goods\textsuperscript{11} to the measurement of that 'aggregate capital' which must appear among the 'endowments'.\textsuperscript{12}

Another feature common to practically all the models reviewed so far is the behavioural assumption concerning maximising agents.\textsuperscript{13} Particularly with regard to technical change, this assumption becomes rather questionable. As argued at greater length elsewhere (Dosi, 1984) and following Nelson and Winter (1982), it is difficult to maintain that maximisation procedures are an adequate representation of the global behaviours of the agents whenever one properly accounts for the fundamental features of
technical change (including uncertainty about choices and outcomes, patterns of search generally embodying tacit heuristics, various kinds of irreversibilities, etc.). It is not only or even primarily a matter of realism of assumptions. The fundamental point is that behaviours are directly relevant also in terms of the equilibrium positions towards which the system might tend to converge. In other words, even the 'static attractor' of the system may well be path-dependent and behaviour-dependent (cf. Nelson and Winter, 1982; Dosi and Orsenigo, 1985).

The less pure theory: the 'heretics'

The discussion so far has focused upon that stream of economic analysis concerned primarily with one theoretical question, namely the determinants of specialisation, and one functional mechanism, namely the adjustment processes induced in the latter by the interdependences between markets, both within each country and between countries. It is a line of enquiry which—despite the great differences in the assumptions on technology, demand, nature of the markets—links Ricardo, the neo-classical school and all those 'revisionist' contributions based on a general equilibrium framework. One of the fundamental premises of such a stream of thought is that trade (or the notional transition from autarky to trade) affects the inter-sectoral (and, sometimes, inter-national) allocation of inputs, quantities and prices, but does not affect the rate of utilisation of the stocks of inputs themselves (and thus the rates of macroeconomic activity). This is straightforward in modern general equilibrium analysis where, as already discussed, full employment of all factors is assumed by hypothesis. It is equally true for that part of Ricardo's Principles concerned with international trade, based as it was on the assumption that

no extension of foreign trade will immediately increase the amount of value in a country, although it will very powerfully contribute to increase the mass of commodities, and therefore the sum of enjoyments. As the value of all foreign goods is measured by the quantity of the produce of our land and labour, which is given in exchange for them, we should have no greater value if, by the discovery of new markets, we obtained double the quantity of foreign goods in exchange of a given quantity of ours, [Ricardo, 1951, p. 128].

Since in Ricardo's model production techniques are given, the assumption concerning an unchanged 'amount of value in a country' is precisely equivalent to an assumption of constancy of the rates of macroeconomic activity throughout the notional transition from autarky to trade. In the history of economic thought, however, one can identify also another group of contributions, highly heterogeneous in scope and nature, seldom thoroughly formalised, heretic in spirit and often produced by outsiders to the dominant economic tradition. In this composite group one may include early economists from the eighteenth and nineteenth centuries, such as the
Reverend Tucker, Count Serra of Naples, Ferrier, List, Hamilton, as well as parts of the analysis of Adam Smith. In more recent times one finds an equally heterogeneous set of writers ranging from some technology-gaps and product-cycle authors (Posner, Freeman, Vernon, Hirsch) to Kaldor, Cornwall and Thirlwall, broadly in the post-Keynesian tradition; 'structuralist' writers in development economics, especially within the Latin American tradition; economic historians, such as Gerschenkron and Kuznets; some modern French writers such as Bye, de Bernis, Lafay and Mistral. Obviously, these contributions are highly different in nature and scope. However, one may state that they have in common, explicitly or implicitly, one or several of the following assumptions:

(i) International differences in technological levels and innovative capabilities are a fundamental factor in explaining the differences in both levels and trends in export, imports and income of each country.

(ii) General equilibrium mechanisms of inter-national and inter-sectoral adjustment are relatively weak, so that trade has important effects upon the rates of macroeconomic activity of each economy. Putting it another way, the growth of each economy is often balance-of-payments-constrained and this constraint becomes tighter or looser according to the levels and composition of the participation of each country in world trade flows. The weakness of price/quantity adjustments between sectors and between countries has to do partly with the nature of technology (fixed coefficients, irreversibilities, etc.) and partly with the nature of demand (sticky baskets of consumption, etc.) As a result, what adjusts in the international arena is world market shares within each sector and, through that, the levels of macroeconomic activity generated by foreign demand.

(iii) That same weakness of general equilibrium adjustments is such that the intra-sectoral distribution of trade shares between countries and their evolution through time can be explained by a set of country-specific absolute advantages and without explicit reference, at least in a first approximation, to price/quantity adjustments between sectors and between factors' returns.

(iv) Technology is not a free good.

(v) The allocative patterns induced by international trade have dynamic implications which may either yield 'virtuous' or 'perverse' feedbacks in the long term.

These assumptions have generally been stated in a rather confused way by the early writers, who did not share the rigour and depth of any Ricardo or Samuelson, and were often motivated simply by policy issues such as protection versus free trade. Nonetheless, they had precious if confused insights into complex problems of economic dynamics which were later neglected in the cleaner but more restrictive formalisations of modern trade theory. For example, Tucker (1774) (quoted also by Hufbauer, 1970) assumes that there is a macroeconomic link between technological
advantages, international competitiveness and incomes, and discusses whether the product-cycle effects induced by the lower wages of the 'poor country' will eventually reverse the competitive position of the 'rich' vis-à-vis the 'poor'. His answer is reassuring for England: continuous technical progress, higher capabilities of accumulation and institutional factors will keep an absolute advantage there, despite the lower wages of the more backward countries. Ferrier (1805) deals with the relationships between trade and rates of macroeconomic activity in the light of the historical experience of the Continental Blockade, arguing that there is a direct negative link between import penetration and employment levels in the relatively backward country due to a generalised technological disadvantage and to the long-term effects that de-specialisation in the most advanced products (in that case, manufactures) exerts upon the capability of progress and accumulation: '... I compare a nation which with its money buys abroad commodities it can make itself, although of a poorer quality, with a gardener who, dissatisfied with the fruits he gathers, would buy juicier fruits from his neighbours, giving them his gardening tools in exchange'. (Ferrier, 1805, p. 288).

Interestingly, Adam Smith was equally aware of the dynamic implications of trade and his position appears almost symmetrical to Ferrier's, from the 'advanced country' point of view. First, he argues, trade has a beneficial effect upon the rates of macroeconomic activities and employment because, in contemporary words, exports increase aggregate demand. This is close to what Myint (1958) later defined as a 'vent-for-surplus' model of trade. Second, the enlargement of the market due to international trade feeds back upon the domestic division of labour and thus on the trends in productive efficiency.

The argument of List (1904), German and nationalist, is directly against Ricardo and Say. The practical matter at stake, as known, was the political advocacy of protectionism and industrialisation. In List's view, there is nothing in the adjustment mechanisms on the international market (in List's terminology, the adjustments 'based on the theory of exchange values') which guarantees dynamic convergence between nations in terms of productive capabilities and incomes (the 'growth of productive forces of a Nation'). In several respects, this view involves much more than an 'infant industry argument', the idea being that the long-term position of each country depends jointly on its degrees of capital accumulation, its global technical and learning capabilities, and a set of institutional factors (social consensus, factory discipline, political conditions). According to List, the adjustment processes set in motion by international trade might well be detrimental to the development of these aspects of the 'national productive forces'. Putting it in modern words, static and dynamic economies of scale and differing income elasticities of the various commodities will lead under free-trade conditions to divergence rather than factor-price equalisation, and to growth polarisation with the concentration of production in one country rather than welfare gains for both partners. In a similar
perspective, these points have been emphasised in much of the early
development/trade/dependency literature (cf. Prebisch, 1950), and in the
historical analysis of the early industrialisation/opening of trade process in
the United Kingdom.

More recently and along the lines suggested by Kaldor (1970, 1975,
1980), Thirlwall and Vines (1983) have formalised such views in a multi-
sector North–South model and have studied the 'consistency conditions'
between the two countries and the various sectors. The Kaldor–Thirl-
wall–Vines approach, while incorporating some ideas similar to earlier
'two-gap' models of development—whereby the growth of the industrialis-
ing countries is shown to be constrained by either saving/investment
capacity or by the foreign exchange requirements—embodies a general
hypothesis that world growth is determined by 'asymmetrical' patterns of
change in technical coefficients and demand composition. In this view,
processes of inter-factorial and inter-commodity substitution in response to
relative prices and excess factor supplies are of minor importance. What
adjusts is the level of sectoral and macroeconomic activity.

An ambitious multi-sector model along similar lines is that of Pasinetti
(1981), whose open-economy version determines the relative rates of
growth between economies in terms of evolution of relative productivities
and income elasticities of the commodities each country produces.

In all these models the difference in the income elasticity of the various
commodities plays a fundamental role and is assumed to dominate upon
the price/quantity adjustments in consumption baskets. Thus, as Thirlwall
(1980) shows, the income elasticities enter into the determination of the
foreign-trade multiplier of each economy (via import propensities and
export elasticities to world income). The other factor is obviously technol-
ogy. 'Polarisation' in innovativeness is shown to imply 'polarisation' in
growth.

Interestingly, while both the Ricardian and neo-classical perspectives
focus upon the determinants of the patterns of specialisation, the set of
contributions reviewed above focuses on the relationship between trade,
levels of activity and growth. In terms of adjustment mechanisms, both
Ricardo and the neo-classical school hold the rates of activity constant and
study trade-induced changes in relative prices and relative quantities;
conversely, the 'heretic' stream often assumes away price/quantity adjust-
ments and studies the link between trade and rates of activity in both the
short and long term.

In order to highlight these differences, one may represent the early
heretic model as follows. Imagine two countries, Portugal and England,
producing two commodities, (wine and cloth) with only one production
factor: labour. Suppose that, at the beginning, the two countries are
absolutely identical: the same technical coefficients, same relative prices,
same patterns of consumption, same absolute prices as expressed in their
respective currencies whose exchange rate is equal to one. Suppose also
the existence of a non-reproducible asset, say, gold, or alternatively
tradable shares representing titles of ownership over the productive activities. Finally, suppose that each economy has some surplus labor which can be mobilised without any extra cost whenever required. Clearly, the two countries, even if opened to the international markets, will not trade. Assume now an across-the-board improvement in the Portuguese technical coefficients which leaves unchanged relative productivities and relative prices. In the perspective of both Ricardo and the neo-classicals still no trade will occur. As Findlay puts it, '... greater technological efficiency cannot be the cause of trade if the relative difference is the same in both goods' (Findlay, 1973, p. 57).

On the contrary, in what could be called a Smith–Ferrier–List model of trade a one-way trade will occur with Portugal progressively gaining market shares on the English market in both wine and cloth. Correspondingly, gold or ownership titles will move from England to Portugal. The rates of macroeconomic activity will grow in Portugal and fall in England. The adjustment process to the Portuguese technological advance will not stop until the exchange rate will have entirely adjusted to the new purchasing power parity determined by the new levels of productivities in Portugal as compared to English ones. It is easy to define the dynamic counterpart of the model. Imagine a continuous flow of technical improvements in Portugal. One will observe a continuously increasing market penetration of Portugal on the English markets. The adjustment process takes essentially three forms.

First, the English currency continues to devalue. Second, gold or ownership titles continue to flow out of England. Third, the rates of activity in Portugal continue to grow and the English ones to fall. Notably, the increasing technological gap is reflected in the changing world market share in each commodity, even if no international specialisation occurs. One could broaden the model, for example, by introducing a third commodity, whisky, which only England can produce due to some natural advantage. Then, under the above assumptions, England will slowly converge toward an absolute specialisation in whisky while her short-term rate of activity and her long-term growth will depend upon the levels and changes in the Portuguese propensity to drink whisky as compared with the English propensity to drink wine and wear clothes.

Needless to say, such a model embodies gross oversimplifications. However, it illustrates probably better the evidence on the free-trade adjustment processes following major technological polarisations than the Ricardian alternative. This is precisely what continental writers from the early nineteenth century had in mind: given the European backwardness vis-à-vis England, laissez-faire regimes would not have yielded mutual gains from trade, but rather would have reduced Europe to a condition more similar to India.

A major factor countering this link between polarisation in technology and in income levels is, of course, the international diffusion of technology. Indeed, most modern technology-gap models focus on the
crucial time element between innovation and imitation abroad as the trade and income-polarising 'reversal' factor.

The basic assumption of modern technology-gap trade accounts is that technology is not a freely, instantaneously and universally available good, but that there are substantial advantages in being first. Thus in Posner's seminal model it is suggested that while technical changes and developments may influence some industries and not others, it is the technical change originating in one country and not in others which will induce trade 'during the lapse of time taken for the rest of the world to imitate one country's innovation' (Posner, 1961, p. 323).

A similar point is made in Freeman's case study of the plastic industry: 'Technical progress results in leadership in production in this industry, because patents and commercial secrecy together can give the innovator a head start of as much as 10-15 years' (Freeman, 1963, p. 22). Once imitation has taken place, more traditional factors of adjustment and specialisation would again take over and determine trade flows. In Hufbauer's words: 'Technology gap trade is . . . the impermanent commerce which initially arises from the exporting nation's industrial breakthrough and which is prolonged by static and dynamic scale economies flowing from the breakthrough' (Hufbauer, 1966, p. 23). There is, of course, nothing necessarily 'impermanent' about these static and dynamic scale economies. Coupled with new or improved product innovations they might well lead to a more or less continuous trade flow.

Product life-cycle theories (Hirsch, 1965; Vernon, 1966) provide an articulated trade picture along similar lines. They also integrate foreign direct investment and view technology as part of a wider set of market structure factors, including entry, product differentiation/standardisation, nature of demand. Vernon's original model is primarily demand-determined: high levels of income and sophisticated demand patterns induce innovative responses of domestic firms. More recently, the introduction of supply factors has dealt with some of the weaknesses of the original model (for a critical assessment see, Walker, 1979). The contributions here relate primarily to theories of innovation and can be seen as an extension of post-Schumpeterian 'evolutionary' models (see Nelson and Winter, 1982; Dosi, 1984) to the international field, where the emphasis is on the dynamic/biological nature of international competition.17

The empirical evidence

The picture which emerges out of the innumerable number of empirical trade studies is, as one might expect, far from uniform. Moreover, the correspondence between theoretical models and empirical tests is generally poor. As Deardorff notes in his thorough review of trade studies,

Empirical tests of the theories are often faulted on the grounds that they test propositions that do not derive rigorously from the theories. The reason is not usually that empirical models are sloppy. Rather, the problem seems to lie in the theories themselves, which are seldom stated in forms that are compatible with the real world complexities that empirical research cannot escape. [Deardorff, 1984, p. 468]

We will organise our review of an even more selected literature with reference to the same themes and approaches discussed above.

A major stream of research, not surprisingly, has been concerned with the explanation of the so-called 'Leontief paradox' within a by and large, orthodox factor-proportions framework. As is well known, Leontief (1953) found that the composition of trade of the United States, clearly a capital-abundant country, was biased in favour of labour-intensive exports and capital-intensive imports. While the typical research strategy in the theoretical field was simply to neglect the potentially disruptive implication of such a falsification of the theory, the empirical strategy focused upon additional variables which could explain away the 'paradox'. This has been one of the analytical procedures which has drawn attention toward technology-related variables, typically labour skills and what has become known as 'human capital'. Many empirical studies, primarily concerned with the US case, found these latter variables to be significantly correlated with the American composition of trade (see, amongst others, Keesing, 1965, 1967; Baldwin, 1971; Harkness and Kyle 1975; Branson and Monoyios, 1977; Stern and Maskus, 1981). Moreover, Leamer (1980) has argued that a proper test of the Heckscher–Ohlin model must not be based on the factor content of trade but on the relative factor intensity of production as compared to consumption. Using this criterion, Stern and Maskus (1981) found that the Leontief 'paradox' did hold for 1958 but not for 1947 or 1971. These empirical findings and refinements seem, at first sight, comforting to the prevailing theory in its generalised version, including a 'technology-production' factor and extending the concept of capital not only to human capital but also to 'intellectual capital', defined as the 'capitalised value of productive knowledge created by research and development' (Johnson, 1970, p. 14). However, one must have severe reservations about these 'revisionist' attempts to accommodate the evidence with a traditional factor-proportion view of trade flows.

First, with regard to the conclusions based on Leamer's methodological suggestions, the results are far from 'non-paradoxical' and depend crucially on the chosen years. They therefore appear not particularly robust.
Second, as argued by Deardorff, the ‘acknowledgement of additional factors of production cannot in theory explain Leontief’s paradoxical results regarding capital and labour’ (Deardorff, 1984, p. 481).

Third, the higher the distance of the underlying model from the original labour/land framework, the lower appears the plausibility of the basic assumptions. As already discussed in the previous section, one can hardly consider ‘capital’ as an endowment whenever it is actually produced under conditions of non-decreasing returns. It is even harder to define R & D as an endowment, for its ‘size’ depends on highly discretionary decisions of firms and public institutions.

Fourth, proper ‘tests’ of the Heckscher–Ohlin model must be based on direct plus indirect factor contents. As discussed at length by Momigliano and Siniscalco (1984), this correct procedure has been followed only by a few studies.¹⁹ The majority of them simply consider direct product characteristics. This methodological difference matters. Thus Italy’s trade performance is negatively correlated with the direct R & D content of each commodity but is positively correlated with the total content (direct plus indirect, via input/output flows) (see Momigliano and Siniscalco, 1984).

Finally, there is the question whether empirical analyses of trade flows can be usefully carried out at the level of intra-country, inter-sectoral studies only. This methodological issue has been raised at a general level by Leamer (1974) and Leamer and Bowen (1981). The problem stems from different technology-specific characteristics which are likely to influence trade flows and can be accounted for only in inter-country, intra-sectoral analysis.

Given all these methodological problems and caveats, it is fair to conclude that most of the empirical studies based on cross-sectoral analyses relating trade flows (either measures of comparative advantages or net exports) to a menu of product characteristics, while useful in presenting the possible regularities in the structural features of domestic supply and their statistical correlation with the patterns of competitiveness, are far from useful in highlighting any causal mechanism explaining international competitiveness and specialisation.²⁰

The empirical validity of the endowment-based theory of trade remains therefore very much subject to debate.²¹ As Hufbauer puts it,

Leontief’s findings dealt an apparently telling blow to the simplistic two-factor version. Various authorities have sought to repair the damage; their work in some respects resembles the tortured efforts of pre-Copernican astronomers. [Hufbauer, 1970, pp. 267–8]

A different line of empirical enquiry has been concerned with the patterns of relative inter-sectoral specialisations based on a simple Ricardian framework. MacDougall (1951–52) showed that the sectoral ratio of US to UK exports was well correlated with relative American and British labour productivities. These results, confirmed by Stern (1962) and Balassa (1963), do not, however, explain the sources of inter-sectoral
differences in productivity and—as has been argued—could be consistent also with a Heckscher–Ohlin model of trade. On the other hand, they could also highlight the mechanisms leading to comparative advantages on the ground of sector-specific gaps or leads in technology.

Empirical studies using the technology-gap trade framework or product life-cycle theory, on the other hand, emphasise in the first instance the inter-country differences in innovativeness as the basis of international trade flows. Rather than inter-industry variations in the technological ‘endowment’ of a specific country, it is the variation across countries in innovativeness within each sector which seems crucial (see, among others, Freeman, 1963, 1965; Hirsch, 1965; Hufbauer, 1966; Tilton, 1971; Dosi, 1984). Most sectoral studies (e.g. on chemicals, plastics, process plants, electronics products, semiconductors; see the authors just mentioned) highlight the dynamic relationship between early innovative leads, economies of scale, learning by doing, oligopolistic exploitation of these advantages, and international competitiveness. As referred to in the introduction, one of the most ambitious attempts of inter-country and inter-sectoral comparison of technology-based and product-cycle-based models as compared to the other explanations of trade flows was carried out by Hufbauer (1970).

Hufbauer found that the commodity characteristics by country were related to a set of country characteristics including variables related to technology, economies of scale, product differentiation and patterns of domestic demand. Whereas some of the proxies used implied high levels of ‘heroism’, they pointed to the widespread existence of country-specific advantages/disadvantages related to technological innovation, national ‘context’ conditions and forms of corporate behaviour different from ‘pure competition’.

Similarly, the findings by Gruber and Vernon (1970), while broadly in line with the Leontief ‘paradox’, highlighted the homogeneity in the structure of exports (and production) among the major industrial countries and their general correlation with per capita GDP. Walker (1979) critically analysed the sectoral evidence on product-cycle patterns of production and exports, finding that there are groups of products which do conform with the prediction of a shift from advanced to intermediate and backward low-wage countries, while other groups appear more in line with straightforward technology-gap theories, whereby the advantage remains over long periods in the most innovative country(ies).

Irrespective of whether the analysis deals with intra-country, inter-sectoral comparisons or inter-national, inter-sectoral ones, an important methodological issue concerns the proxies used for the technology variable. With the exception of Davidson (1979), Pavitt and Soete (1980), and Soete (1980, 1981), most empirical studies use technology input proxies, such as R & D expenditure or R & D employment. Yet the exact relationship between technology input and technology output remains unclear. Most technology-gap models, however, by emphasising the crucial role of new products and process innovations, make explicit the need for
using a technology output proxy instead of an input proxy in explaining international trade flows.

Some interpretative suggestions

As we have discussed at greater length elsewhere (Dosi, Pavitt and Soete, 1988), the empirical evidence on the composition and dynamics of trade flows can be interpreted within what we consider to be a more satisfactory interpretative framework based on widespread technological gaps among countries, generally non-clearing markets, 'Keynesian-Kaldorian' links between international competitiveness and macro-economic rates of domestic activity. We also tried there to account for a few 'stylized facts' on which this interpretation is based.

First, the international distribution of innovative efforts and innovative results is far from homogeneous, even with the OECD countries. The 'club of the innovators' comprises not much more than a dozen countries, has been relatively stable in its membership for almost a century—with only one major entry (Japan), and shows interesting patterns of evolution in the internal ranking of countries (e.g. Germany and the USA overtaking England at the turn of the century as the major source of innovations, a very quick catching-up process by Japan and to a lesser extent some European countries, such as Italy after the second world war).

Second, these differences in innovative capabilities correspond to equally wide differences in labour productivities. Remarkably, as much as one can infer from imperfect statistical evidence, these differences do not correlate with analogous differences in capital/output ratios. That is, differences in the 'production functions' rather than differences in 'endowments' appear to be the fundamental feature of the international system of production.

Third, cross-sectoral analysis shows a high sectoral specificity in the opportunities and propensities to innovate and patterns of inter-sectoral distribution of one country's innovative strength and weakness which defy traditional explanations (e.g. why is Switzerland strong in pharmaceuticals and Sweden in mechanical engineering?).

Fourth, as regards trade flows, one obviously observes long term changes in the patterns of national 'revealed comparative advantages' but these changes are often inter-linked with country-wide changes in world market shares which often occur in all (or most) sectors, although at different rates (e.g. the British generalised decline or the Japanese rise).

It is against this background of stylised facts that we have started constructing an alternative model of technology and trade.

Technology, we argue in line with several other chapters in this book, cannot be reduced to freely available information or to a set of 'blueprints': on the contrary, each 'technological paradigm' with its forms of specific knowledge yields relatively ordered cumulative and irreversible patterns of technical change, which are also country-specific.
A fundamental implication of such an analysis of technical change is also a theory of production whereby different ('better' and 'worse') techniques, products and firms co-exist at any point in time.

Thus, the main mechanisms of change over time are evolutionary processes of innovation and diffusion of unequivocally better techniques and products. This interpretation, partly modelled elsewhere (Dosi, Pavitt, and Soete, 1988) can account for the continuous existence of technology gaps between firms and between countries and for the conditions of convergence or divergence in inter-firm and inter-national technological capabilities, according to the degrees of opportunity, cumulativeness and appropriability that each technology presents.

In this view, the degrees of innovativeness of each country in any one particular technology are explained—as regards their origin—through the inter-play between (i) science-related opportunities, (ii) country-specific and technology-specific institutions which foster/hinder the emergence of new technological paradigms, and, (iii) the nature and intensity of economic stimuli, which stem from abundance of particular inputs, or, alternatively, critical scarcities of inputs, specific patterns of demand and levels and changes in relative prices. In this sense, the interpretation suggested here accounts for the taxonomic evidence presented by the particular theories of 'market-induced' innovations (e.g. product-cycles, demand-pull, relative-price inducements) and incorporates them in what we believe to be a more general view of the innovative process: certainly there is a wide variety of economic inducements to innovation, but these belong to the necessary although not sufficient conditions. Sufficiency is provided by the degrees of matching/mismatching between these generic market opportunities and the institutional conditions related to the scientific/technological capabilities available in each country, the 'bridging institutions' between pure science and economic applications, the expertise embodied in the firms, the patterns of organisation of the major markets, the nature and impact of public policies.

Over time, capital accumulation and technological accumulation are inter-linked so that irreversible improvements in input efficiencies and search/learning processes feed back on each other. In some respects, our analysis overlaps with the question concerning 'why growth rates differ' (cf. the next chapter by Fagerberg). However, our interpretation is the polar opposite to the traditional one (but consistent with Fagerberg's): instead of explaining differences between countries in terms of differential endowments, we argue that the fundamental inter-national differences relate to the country-specific conditions of technological learning and accumulation.

The model of trade, only briefly hinted at here, takes these regularities as its starting point, and is based on the general existence of technological differences—that is: differences in input efficiencies, in product qualities and in performance—between countries. These gaps, we argue, are the equivalent of the Smithian/Ricardian 'absolute advantages' and determine two fundamental processes of adjustment between and within countries.
First, inter-sectoral intra-national differences in technology gaps/leads yield a tendency toward relative specialisations in the sectors of 'comparative advantages'. This is the familiar mechanism of adjustment described in the Ricardian and, under different assumptions, neo-classical literature.

Second, and at least as important, intra-sectoral gaps/leads between countries yield adjustments in world market shares, as suggested by some of the 'heretic' contributions reviewed above. This adjustment process relates to the notion of 'absolute' or 'structural' competitiveness of each country. It is an 'absolute' notion in the sense that it does not relate to any inter-sectoral comparison ('I am relatively better in this or that'), although it is obviously relative to other countries ('I am better or worse than country B or C').

The link between absolute advantages/disadvantages and world market shares (or per capita exports), within each sector and for each country as a whole is empirically quite robust: in previous tests (Soete, 1981, Dosi and Soete, 1983), different degrees of innovativeness and differential productive efficiency perform as a good predictor of the inter-national distribution of export flows in more than three quarters of the forty industrial sectors that we considered, despite the admittedly imperfect nature of our statistical proxies.

Moreover, country-wide changes in innovativeness and input efficiencies are a significant part of the explanation of the long term changes in national export shares in the world markets.

In our interpretation and in line with the arguments advanced by Pasinetti (1981), comparative advantages are obtained only as a by-product of both intra-national inter-sectoral changes in inputs allocations and changes in the absolute amount of inputs each economy employs to produce for changing shares in the world market. That is, from a dynamic perspective, revealed comparative advantages appear to be the ex post result of sector-specific and country-specific learning dynamics, and of the related inter-national intra-sectoral changes in competitiveness of firms and countries.

This analysis can easily be linked with a 'Keynesian' view of the determination of the rates of macroeconomic activity of each economy. Unlike neo-classical trade analyses—which impose market-clearing in the model—and unlike also Ricardian trade models—which, in order to identify equilibrium specialisations, generally assume steady-state growth, our interpretation requires changes in the levels of macroeconomic activity of each economy in response to changes in international competitiveness (i.e. relative changes in innovativeness, input efficiency, organisational competence of domestic firms, etc). Thus, the link between absolute advantages/disadvantages and world market share (or per capita exports) is theoretically consistent with a determination of domestic aggregate demand via the foreign trade multiplier.

Elsewhere (Dosi, Pavitt and Soete, 1988), with the help of a simple formal model, we show that international gaps in technology define the
boundaries of both 'Ricardian' processes of adjustments in specialisations and 'Keynesian' adjustments in the rates of macroeconomic activity. From a dynamic point of view, it is the evolution in the innovative/imitative capabilities of each country which shapes the trends in the relative and absolute rates of growth of the tradeable sector of each economy.

These theoretical propositions are broadly consistent with the empirical evidence reported and presented in Pavitt and Soete (1981) and in the next chapter Fagerberg: the links between innovativeness and macroeconomic growth, in cross-country analyses over the past eighty years, appear to be rather strong, although the precise forms of that relationship depend on each particular phase of development (i.e. each particular ‘regime of international growth’, as hinted in Boyer’s chapter).

Conclusions

There are as will be obvious from the review section still major gaps in our understanding of the role of innovation in international trade. One is only beginning to analyze (i) the determinants of different national capabilities to innovate, imitate, and, generally exploit competitively the innovative efforts; (ii) the nature and relative importance of the various adjustment mechanisms within and between countries following such innovative processes; (iii) the relationship between sector-specific patterns of competiveness and ‘general equilibrium’ factors, in the broader sense, linked to relative prices, inter-sectoral capital and labour mobility, etc; (iv) the implications of economies of scale, dynamic increasing returns (see in particular Arthur’s chapter in this book), oligopolistic forms of market organisation, international investment and all the factors which generally go under the heading of ‘imperfect competition’; (v) the long-term relationship between innovation, trade and growth. All these issues are as much in need of empirical research.

Our own approach as sketched out above, can be summarized by the following propositions: First, the ‘microfoundations’ of international trade analysis, consistent with the available evidence, should be found in the extension of an ‘evolutionary’ interpretation to the international arena. Second, in such evolutionary dynamics, what appears to be, ex post, a ‘comparative advantage’ is in no proper sense the result of any ‘endowment’ but the outcome of processes of learning—innovation, imitation, organisational change—which have both sector and country specifics. Third, the innovative process, by allowing various sorts of (static and dynamic) increasing returns generally entails also forms of market interactions different from perfect competition. Fourth, these same properties of technical change imply the possibility of those irreversible processes discussed in Arthur’s chapter, and, thus, also, from a normative point of view, the possibility of ‘virtuous’ or ‘vicious’ circles in innovativeness, competitiveness and growth. Fifth, the micro-economic and sectoral levels
and changes in international competitiveness, determined under conditions of continuous technological learning and limited short-term substitution in both production and consumption, appear also to represent the micro-foundations of many macro-economic analyses, in particular those with some 'Keynesian' ascendency whereby economic systems seldom hit any powerful scarcity constraint, but are limited in their growth by aggregate demand and foreign balance requirements.

The largest part of the theoretical analysis of these processes is still to be done. However, we would argue that these contain some of the most promising links between the evidence on trade flows and patterns and the interpretations of innovation, industrial evolution and patterns of growth discussed in the other chapters of this book.

Notes

1. Extensive reviews of the trade literature can be found in Bhagwati (1964), Chipman (1965/66), Stern (1975), and Jones and Kenen (1984), and more specifically on the issues related to technology and international trade, in Hufbauer (1966, 1970), Chesnais and Michon-Savarit (1980), Aho and Rosen (1980), Dosi and Soete (1983), Soete (1985) and Lyons (1986).

2. That is the Heckscher–Ohlin theorem, stating that the relative specialisation of each country is in those commodities which use intensively those factors which are relatively abundant in that same country.

3. Such as, for example, the analytical treatment of those cases with more commodities than factors, etc.

4. Of course this is necessarily so if the economies of scale are internal to each firm.


7. This line of enquiry is in many ways an attempt at a synthesis between the Heckscher–Ohlin–Samuelson model and Linder's model (cf. Linder, 1961). For a model accounting also for multinational investment, see Helpman (1984).


9. That is, a general equilibrium model with sector-specific and inter-sectoral immobile factors (see Jones and Neary, 1984).


11. Interestingly, the standard neo-classical way out of the difficulties with regard to capital measurement has been, in the closed economy case, through general equilibrium models of Walrasian ascendency. This possibility is generally
precluded in the field of international trade, since the specification of a long vector of 'endowments' implies nearly tautological conclusions. It is of little interest, as Corden puts it crudely, to have a 'theory' which says 'that Switzerland has a comparative advantage in watches because she is watchmaker-intensive or that the United States export 747s because she is intensive in firms or engineers capable of making 747s' (Corden, 1979, p. 9.). In trade-related capital theory the standard procedure is simply to assume that the measurement problem does not exist ex hypothesi: 'Suppose that . . . the common technology has no factor-intensity reversal . . .' (Ethier, 1981, p. 274).

12. This is not the place to discuss these issues. Suffice to make one remark. With time and reproducibility of capital (in the form of machines, etc.), the 'dynamic' equivalent of the timeless Heckscher-Ohlin-Samuelson model becomes one where the 'scarcity constraints' are the rate of growth of the labour supply and the saving rate. This strictly pre-Keynesian view of the growth process raises many questions: how does one account for all periods and countries in modern history characterised by structural unemployment of one kind or another? Do 'scarcity constraints' functionally define the system even in the presence of continuous technical progress and widespread economies of scale? Where is there proof that it is the rate of saving which determines the rate of investment and not vice versa such as in the Keynesian–Kaleckian view? Where is the evidence that countries characterised by higher saving propensities also present higher capital 'endowments' and relatively capital-intensive exports?

13. This is equally true for the models of 'pure' competition as well as those based on imperfect competition or oligopolistic strategic interaction.

14. Obviously, this assumption is necessary to base the analysis on unit functions, indifference curves, isoquants, etc.


18. Some scattered and less convincing evidence exists also for Sweden (Bergstrom-Balestahl, 1979) and Canada (Hanel, 1976). Thorough reviews can be found in Deardorff (1984) and Omida (1984).

19. To our knowledge, since Leontief (1953, 1956), the total factor contents has been used only by Carlsson and Ohlsson (1976).

20. One can interpret in this way also the results of those studies which include among the 'independent' variables a lot of factors of which only few can be derived by a standard factor-proportion model; cf. for example, Wells (1969), Moral (1972), Finger (1975b).

21. Romney Robinson: '. . . in models which demand that all phenomena be subsumed either under production functions or under factor availability, it means that there is nothing left on the supply side but factor proportions to account for price differences. Yet if different production functions were admitted, then the theory, confronted with evidence of trade contrary to that
indicated by factor supplies, could always take refuge in the plea: ‘different production functions’. But that would reduce it to a banality. *Any* pattern of trade could be explained in such terms’ (Robinson, 1968, p. 6–7).

22. See Falvey (1981) and Deardorff (1984). Bhagwati (1964) challenged the theoretical foundations of these ‘Ricardian’ tests. The critique is somewhat surprising in the light of the relatively little amount of *ad hoc* assumptions required to derive the tests from the theory, especially as compared to those necessary to the factor-proportion models.

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