9
Conclusions

Despite the intuitive relevance of technical change for international competitiveness and economic growth, few studies have systematically addressed these issues both from an empirical and theoretical perspective. This book has attempted such an undertaking. We began by setting out some of the – in our view – most characteristic features of technological innovation in modern market economies. We then analysed the impact of these features on the composition of and changes in international trade flows, and tried to establish formally the relationship between innovativeness, trade performance and patterns of economic growth.

Our investigation started with a critical overview, a personal assessment, of the state-of-the-art in the economic analysis of technology and trade (Chapter 2). We discussed whether the neo-classical theory of trade – in its 'canonic' form or in some modified version – could adequately account for technical change over time and differences in technological capabilities between countries. Our conclusion, with the exception of some of the contributions falling under the heading of 'new' trade theory (Markusen, 1985, 1989), was essentially negative. The 'canonic' version of the theory explains trade flows exclusively on the grounds of differences in 'endowments' between countries and identity in their technological capabilities. We reviewed several attempts to relax such an hypothesis and introduce international differences in technology and/or technical change over time. These attempts – we concluded – were generally not satisfactory for three main reasons.

First, whenever some more 'realistic' assumption on technology was introduced into the model, the theory generally showed a striking lack of robustness; most predictions stemming from the 'canonic' model no

longer appeared to hold, not even in approximate form. It goes without saying that this is a serious theoretical weakness.

Second, the most relevant properties of technical change could only be introduced into the theory in a piecemeal fashion, one at a time, and with a significant amount of 'adhocry'. It is yet to be demonstrated that any version of a neo-classical trade model can incorporate simultaneously all the main features of innovation.

Third, irrespective of the particular version of the model adopted, the crucial adjustment mechanisms that the theory postulated were based on changes in relative prices and relative quantities linked to relative scarcities. Practically by definition, such assumptions must be questioned, when explicit account is taken of technical change which continuously tends to overcome scarcities and increase input efficiency.

The evidence on the relationship between technological innovation and trade, we concluded, thus demands a different theoretical representation whereby international technological differences, disequilibrium processes, forms of increasing returns, all appear as basic underlying assumptions.

We acknowledged the major contribution of 'new' trade theory in this area, but rather than pursuing on a similar trajectory, set out from the economics of technological change. In Chapter 3, we first tried to identify the main 'stylised facts' which a theory of technology and trade should explain. On the grounds of previous empirical work, we identified some significant regularities in the international and intersectoral distribution of innovative activities.

First, the international distribution of innovative efforts and innovative results appeared far from homogeneous, even within the group of relatively rich OECD countries. The 'club of innovators' comprises not much more than a dozen countries and has remained relatively stable for almost a century – with only one major entry (Japan). It nevertheless showed some interesting patterns of evolution in the internal ranking of countries (e.g. Germany and the United States overtaking England at the turn of the century as the major sources of innovations and very rapid catching-up by Japan in the post-War period).

Second, these differences in innovative capabilities appeared to correspond to equally wide differences in labour productivities. As much as we could infer from very imperfect statistical evidence, these differences did not seem to correlate with analogous differences in capital/output ratios. In other words, differences in 'production function' rather than differences in 'endowments' appeared to be the fundamental feature of the international production system.

Third, the cross-sectoral analysis pointed to a high sectoral specificity

in the opportunities and propensities to innovate and patterns of intersectoral distribution of one country's innovative strength which defied traditional explanations (e.g. why was Switzerland strong in pharmaceuticals and Sweden in mechanical engineering?).

Fourth, with regard to trade flows, long-term changes in the pattern of national 'revealed comparative advantage' were often interlinked with country-wide changes in world market shares which occurred in all sectors (e.g. the British general decline or the Japanese overall rise).

Against this background of apparent facts and trends, we then constructed an alternative model of technology and trade, set out in Chapters 6 and 7.

In Chapters 4 and 5, we analysed first, however, some features of the nature, origins and implications of the international and intersectoral differences in innovativeness identified in the preceding chapter.

Technology, we argued, cannot be reduced to freely available information or to a set of 'blueprints'. Following some of the analyses of the process of technical change by Rosenberg, Nelson, Winter, Sahal and many others, we proposed a view of technology embodying specific, local, often tacit, and only partly appropriable knowledge. Each set of technical principles, search procedures, forms of expertise – which we called 'technological paradigms' – would lead from this perspective to relatively ordered cumulative and irreversible patterns of technical change: so-called 'technological trajectories'.

Paradigms and trajectories appeared to differ in different sectors, according to the knowledge base on which they would draw, the strength of their linkages with pure science, the nature of the innovative search processes, the degrees of embodiment of technical advances in capital equipment and the forms of private appropriation of the economic benefits from innovation. On the basis of some of these indicators, we were able to develop a sectoral taxonomy of the patterns of production and use of innovations. We observed some remarkable differences in the contribution of each sector to the innovative output of the economic system, and identified a small set of patterns through which innovation would be 'produced' or adopted within the same sector or other sectors, and some typical market structure forms associated with particular patterns of innovation.

An important implication of our analysis of technical change is the support for a *theory of production* whereby different ('better' and 'worse') techniques, products and firms co-exist at any point in time. The main mechanism of change over time thus appears to consist of an evolutionary process of innovation and diffusion of unequivocally better techniques and products. The model developed in Chapter 5 can account

for the continuous existence of technology gaps between firms and between countries and for the conditions of *convergence* or *divergence* in interfirm and international technological capabilities, according to the degrees of opportunity, cumulativeness and appropriability that each technology presents.

From such a perspective, the degree of innovativeness of each country in any one particular technology is explained – as regards its origin – through the complex interplay between (i) technology-related opportunities; (ii) country-specific and technology-specific institutions which foster/hinder the emergence of new technologies; and (iii) the nature and intensity of economic stimuli, which stem from abundance of particular inputs, or, alternatively, critical scarcities, specific patterns of demand and levels and changes in relative prices. In other words, the interpretation suggested accounts for the evidence presented by some of the particular theories of 'market-induced' innovations (e.g. product-cycles, demand-pull, relative-price inducements) and incorporates such theories in what we believe to be a more general view of the innovative process.

There is certainly a wide variety of economic inducements to innovation, but these belong to the necessary, although not sufficient, conditions. Sufficiency is provided by the degree of matching/mismatching between these generic market opportunities and the institutional conditions related to scientific/technological capabilities available in each country, the 'bridging institutions' between pure science and economic applications, the expertise embodied in the firm and the pattern of organisation of the major markets.

Over time, we argued, capital accumulation and technological accumulation are interlinked so that improvements in input efficiencies and search/learning processes feed back on each other. In some respects, our analysis overlaps with the question of 'why growth rates differ'. However, our interpretation is the opposite of the traditional one: instead of explaining differences between countries in terms of differential endowments, we argue that the fundamental international differences relate to the country-specific conditions of technological learning and accumulation.

In Chapter 6, we utilised these insights into the innovative process as the starting point for the development of a model of trade based on the general existence of technological differences between countries. These gaps, we argued, were the equivalent of Smith's 'absolute advantages' and determined two fundamental processes of adjustment between and within countries.

First, intersectoral, intranational differences in technology gaps would lead to a tendency toward relative specialisation in the sectors of

'comparative advantages'. This is the familiar mechanism of adjustment described in the Ricardian (and, under different assumptions, in the neo-classical) literature.

Second, and at least as important, intrasectoral gaps between countries would lead to adjustments in world-market shares. This other adjustment process was, in our view, closely related 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 intersectoral comparison ('I am relatively better in this or that'), although it obviously has a relative country content ('I am better or worse than country B or C').

The link between absolute advantages and world-market shares, within each sector and for each country as a whole appeared to be empirically quite robust. In our tests, different degrees of innovativeness and productive efficiency appeared good predictors of the international distribution of export flows in more than three-quarters of the forty industrial sectors considered.

Most of the trade literature focusses almost exclusively upon the origins and effects of 'comparative advantages'. In our model, revealed comparative advantages are obtained only as a by-product of both intranational, intersectoral changes in inputs allocations and changes in the *absolute* amount of inputs that each economy employs to produce in response to changing shares in the world market.

This analysis, as we tried to illustrate in Chapter 7, can easily be linked with a 'Keynesian' view of the determination of the rates of macroeconomic activity of each economy. Unlike neo-classical trade analysis – which generally imposes market-clearing – and unlike Ricardian trade models – which generally assume steady-state growth – the trade model in Chapter 6 allows, and indeed requires, changes in the levels of macroeconomic activity of each economy in response to changes in international competitiveness. Thus, the link between absolute advantages and world-market shares is theoretically consistent with a determination of domestic aggregate demand via the foreign-trade multiplier. In Chapter 7, we analysed in detail the relationship between such international differences in technology, intersectoral mechanisms of specialisation, and macroeconomic growth.

With the help of a simple formal model, we illustrated how international gaps in technology would define the various boundaries of both 'Ricardian' processes of adjustment in specialisation and 'Keynesian' adjustment in the rate of macroeconomic activity. From a dynamic point of view, it could be established that it was the evolution in the innovative/imitative capabilities of each country which shaped the trend

in the relative and absolute rates of growth of the tradeable sector of each economy.

These theoretical results appeared broadly consistent with the evidence we were able to collect. We found that the links between innovativeness and macroeconomic growth, in cross-country analyses over the past eighty years, were rather strong, although the precise form of that relationship depended on each particular phase of development.

In Chapter 8, we finally discussed, albeit briefly, some of the normative implications of our analysis. Certainly, the interpretative, much more complex framework did not allow us to draw the sort of elegant, if misleading, recipes on 'Pareto optimality' of standard trade analysis. The complexity of the innovative process, the multiplicity of adjustment mechanisms and the variety of institutional frameworks can hardly be judged on simple and immutable yardsticks.

However, our theoretical approach does allow a normative counterpart. We were able to identify some general conditions under which conflicts between 'static' (or 'allocative') efficiency and 'dynamic' efficiency (related to innovative and demand dynamism) could arise. Such conflicts, we argued, would be more likely to occur in countries well below the technological frontier. Any judgement as to the preferred trade regime should therefore also take into account an evaluation of the relationship between technological gaps, market signals and conditions of technological accumulation under the different regimes. One must also distinguish between policies related to the emergence of new technological paradigms and those fostering 'normal' technical progress along established trajectories. Historically, we argued, almost unconditional 'free trade' regimes appeared to be the most suited for technological dynamism and growth within established technological paradigms and particularly in the case of countries near or at the technological frontier.

In retrospect, it is probably fair to say that in focussing on the tacit, firm-specific and cumulative features of technological change and the long-term historical evidence of the OECD countries' trade and growth performance, we might have underemphasised some of the international technology diffusion features which seem characteristic to today's multiplicity of strategic technology alliances and agreements between the largest firms in the OECD area. Maybe but maybe not.

We would rather argue that the significant growth of such international technology agreements between firms is precisely the illustration of the crucial firm- and country-specific technological advantages rooted in skills and knowledge. For firms and countries to access such knowledge simple 'transfer' of knowledge bought at the prevailing market price will, generally, be insufficient. Rather it will involve access

to the other firm/country's technological expertise and skills, including the knowledge about the 'foreign' institutional framework, foreign suppliers and users (see also Mowery and Rosenberg, 1989).

The trend towards the internationalisation of science and technology is far from being a negation of the firm- and country-specific nature of much technological advance. In our view, such a 'new' globalisation trend is more a reflection of new ways in which firms are increasingly using to try to overcome the firm- and country-specificity and cumulativeness of technological change.

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