2 Technical change theory and international trade competition

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INTRODUCTION

Historians and contemporary practitioners in both industry and government are well aware of the significant influence that technology and innovative activities are having on international competitiveness. From the most recent OECD or UN documents to the various individual countries' international think-thank recommendations, the importance of technical change as 'chronic disturber of existing patterns of comparative advantage'\(^1\) as well as an essential factor in the achievement of the necessary adjustment to structural change resulting from technical change itself\(^2\) is by now well recognized. In a similar way, the most recent Economic Report of the President\(^3\) recognizes the increased 'international scope of science and technology' during the 1980s and subscribes to the view expressed in the earlier Report on US Competitiveness linking directly the erosion of the international competitiveness of the US during the 1960s and 1970s to deficient investment in innovative activity in the USA as compared with its major industrial competitors.\(^4\)

Economists, too, over the past thirty years have become increasingly aware of the importance of technology and innovation. This they have done partly as a result of empirical studies on the determinants of economic growth and trade performance and partly as the result of new insights into international trade theory following on from the formal introduction of imperfect competition in international trade models. While significant progress has been made in the most recent period, analysis has nevertheless been constrained by two major difficulties: inadequate data measuring 'domestic' and international innovative activities and – despite the introduction of some dynamic features – the continual reliance on a theoretical framework in which static distributional issues remained the centre piece of trade analysis.

With regard to the latter, as Vernon noted in his introduction to the influential readings on The Technology Factor in International Trade, 'researchers have an extraordinary capacity to screen out the evidence that does not fit well with their preconceptions; to relegate uncomfortable observations to the dustbins of the unconscious; or, better still, to reshape the observations so that they may be
perceived in a way that eliminates the discomfiture.\textsuperscript{5} Still, twenty years after Vernon’s remarks, a good deal of analysis on technology growth and international trade has a ‘reductionist’ flavour, attempting more often than not to squeeze genuine dynamic problems of innovation, learning, uncertainty and change into the more familiar cloth of endowments, relative scarcities and optimization under budget constraints.

**STRATEGIC TRADE THEORY AND TECHNICAL CHANGE**

Recent ‘new international economics’\textsuperscript{6} have attempted to introduce some dynamic learning features associated with economies of scale and international rivalry. The policy conclusions emerging from this literature, particularly the theoretical support for infant industry support in a number of industries, has undoubtedly questioned much of the prevailing wisdom in trade policy. As Dixit pointed out in his contribution to Krugman’s celebrated book on strategic trade policy: ‘recent research contains support for almost all the vocal and popular views on trade policy that only a few years ago struggled against the economists’ conventional wisdom of free trade. Now the mercantilist arguments for restricting imports and promoting exports are being justified on grounds of ‘profit sharing’. The fears that other governments could capture permanent advantage in industry after industry by giving each industry a small initial impetus somewhere down the learning curve now emerges as the result of impeccable formal models. The claim that one’s own government should be aggressive in the pursuit of such policies because other governments do the same is no longer dismissed as a non sequitur.’\textsuperscript{7}

Such strategic trade theories have brought to the forefront many features which appear to be, at least at first sight, of particular relevance to the analysis of technical change and international trade. The importance of monopoly rents, of profit sharing and of strategic trade manipulation seem to be of particular relevance to many high-tech industries. Furthermore, the actual emergence of these new theories on the US academic scene occurred at a time of increasing fear in the USA of the Japanese trade and technology challenge.

While sympathetic to any attempt at introducing in trade theory some features of the ‘imperfect’ world we live in, it is difficult not to be very critical both of the way in which the technology factor has been introduced in such new trade theories and the simplistic policy recommendations which appear to emerge from the normative implications. The interpretation given to technology in the new trade vision is indeed only a poor reflection of the complexity of the process of technological change and innovation. It could be said that the simplicity of the way technological change is reduced to ‘learning curves’ in these recent trade theories is reflected in the simplicity of the policy recommendations of how to slide faster along such learning curve.

_Process of technological change and innovation_

In the next few pages we discuss, albeit briefly, some of the most characteristic features of technological change and innovation and as well as their implications
for international trade flows. This leads us to the formulation of an alternative trade model based on some previous work and described in general terms in Section 3. Finally, we discuss in Section 4 some broad plans within the context of the further harmonization of the European Community’s (EC’s) internal market.

A more careful analysis of the process of technological change and innovation brings to the forefront a number of specific features some of which are more fundamentally at odds with the traditional economic view on ‘technology’. First, technology in essence cannot be reduced to freely available information or to a set of ‘blueprints’. Following some of the analyses of the process of technical change of Rosenberg, Nelson, Winter, Sahal, Freeman, Dosi and Pavitt, technology must be viewed as embodying specific, local, often tacit, and only partly appropriable knowledge. Each set of technical principles, search procedures, and forms of expertise – which Dosi has 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 appear 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, Pavitt has developed a sectoral taxonomy of the patterns of production and uses of innovation whereby significant differences in the contribution of each sector to the innovative output of the economic system could be identified.

Second, and as emphasized by Nelson in particular, the widely accepted representation of ‘technical progress’ as a shift in the production function resulting from disembodied or embodied technical change does not adequately represent the more complex reality which emerges from a variety of industry and firm-based studies. It is a popular economic assumption to represent technology as exogenously generated and applicable either as information or as embodied in producer goods. However, in most sectors technology is generated endogenously.

Third, an important implication of such an analysis of technical change is the support for a theory of production whereby different (‘better’ and ‘worse’) techniques, products and firms coexist at any point in time. The main mechanism of change over time appears therefore to consist of an evolutionary process of innovation and diffusion of unequivocally better techniques and products.

Fourth, at the international level, such a view of technology 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 international technological capabilities according to the degrees of opportunity cumulativeness and appropriability that each technology presents.

Fifth, from such a perspective, the degree of innovativeness of each country in any one particular technology is explained – with regards to its origin – through the complex inter-play between (i) science-related opportunities, (ii) country-specific and technology-specific institutions which foster or hinder the emergence of new technologies; and (iii) the nature and intensity of economic stimuli which stem from the abundance of particular inputs, or, alternatively, critical scarcities, specific patterns of demand and levels and changes in relative prices. The interpretation suggested accounts, in other words, 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 a more general view of the innovative process.

Sixth, 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 or mismatching that exists 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 firm and the pattern of organization of the major markets.

Seventh, over time, capital accumulation and technological accumulation are interlinked so that improvements in input efficiencies and search or learning processes feed back to each other. In some respects, such an analysis overlaps with the question concerning 'why growth rates differ'. However, the interpretation is opposite to the traditional one: instead of explaining differences between countries in terms of differential endowments, the question is now 'how and why are such international differences related to the country-specific conditions of technological learning and accumulation?'

The implications of these and other discrepancies between traditional 'economic theory' assumptions and what could be viewed as the 'stylized' empirical reality have already been highlighted by many recent contributions to the economics of technological change. From a microeconomic perspective, a satisfactory theory will indeed have to be based on assumptions on the actual behaviours and characteristics of technology, innovation and competitive processes that can account for the prevailing observed behaviour at the level of the firm and the observed characteristics of the pattern of international trade.

In many ways, the emphasis of such a theory would be the opposite to the conventional one. Conventional trade theory, whether classical, neo-classical or 'new', has focused primarily on allocative optimality for given techniques and has consequently obscured the importance of differences in techniques and product characteristics between countries and neglected the analysis of their origin. It is quite evident, for example, that the wide international differences in per capita income stem primarily from the joint effect of differences in the degree of capital accumulation and differences in technology rather than simply from differences in relative prices (or 'distortions' in the price mechanism).

Technology, trade and growth

The investigation of all these phenomena mentioned above developed separately from trade theories, which did not take technology gaps as one of the fundamental facts from which to start theorizing. This applies in different ways to both 'classical' and neo-classical theories. The latter excludes from the core of the model the implications of inferiority or superiority of techniques between countries for the validity of the most general theorems to hold, such as international factor price equalization. The former allows the existence of such international technological differences, but - as in the 'neo-Ricardian' re-formulations10 - it takes a rather general and agnostic view, describing the equilibrium
specializations irrespective of the nature of the techniques available in each country.

Elsewhere\textsuperscript{11} we developed some hypotheses on the determinants of trade flows in those cases where techniques and product technologies can be univocally ranked, irrespective of domestic income distribution and relative prices. Technology gaps, we argued, are of paramount importance in determining the participation of each country to international trade flows and, through that, the maximum levels of income each country can attain, compatible with the foreign balance constraint. Some previous empirical results,\textsuperscript{12} admittedly based on highly imperfect data, point to the dominance of a set of absolute advantages upon the factors pushing towards comparative advantages and specialization. In other words, the international composition of trade by countries within each sector appears to be explained essentially by technological gaps, while comparative advantage mechanisms appear to be of lesser importance.

In so far as technology gaps and their changes are a fundamental force in shaping international competitiveness, their impact on domestic income, by inducing and/or allowing relatively high rates of growth via the foreign trade multiplier, will be significant. However, the 'virtuous circle' between technological levels, foreign competitiveness and domestic growth is not entirely automatic and endogenous to the process of economic development. Country-specific and sector-specific innovative or imitative capabilities can be isolated as one of the single most important factors which originate these 'virtuous circles' and contribute to explanations of the patterns of international convergence or divergence in terms of trade performance, per capita incomes and rates of growth.

From such a perspective, it is the relationship between technology, trade and growth which is at the centre of the analysis, rather than the question about the short-term gains from trade stemming from the open-economy allocation of resources which is so crucial in the conventional view. The latter are indeed in their very nature 'once-and-for-all' gains: their dynamic relevance concerns the link between the 'static' pattern of allocation and the long-term performance of the economy. The empirical findings reported in Dosi, Pavitt and Soete (1990) are broadly consistent with the theoretical model. The most important conclusions can be summarized as follows:

1. A variety of science and technology measures – R & D, patenting and innovation counts – gives a consistent picture of the aggregate international distribution of innovative activities among countries. Innovative activities are concentrated in relatively few countries. Although there have been significant changes since the beginning of this century in the relative importance of these countries, there has been only one major newcomer to the group, Japan.

2. International differences in innovative activities are reflected in differences in shares of world exports in most sectors, and in manufacturing as a whole.

3. Export performance is positively associated with differences in per capita innovative activities and differences in labour productivity.

4. Changes in trade performance are more strongly associated with changes in innovative activities than changes in relative labour costs.

5. Since the beginning of the century, international differences in per capita income have been closely related to international differences in per capita innovative activity. International differences in the rate of growth of per capita income have
been associated with similar differences in the rate of investment and in the rate of
growth of innovative activities.

The evidence on the relationship between technological innovation and trade
therefore demands a different theoretical representation, rather than an attempt at
providing syntheses between traditional trade theory and specific partial features of
the innovative process.

TOWARDS AN ALTERNATIVE MODEL OF TRADE, GROWTH AND
TECHNOLOGY

It is impossible in these few pages to give a detailed account of what these insights
on the innovative process sketched out above would imply as a starting point for the
development of a model of trade based on the general existence of technological
differences between countries. For this, the interested reader is referred to the
detailed analysis of Dosi, Pavitt and Soete which is referred to above. Technological
differences between countries are to some extent the equivalent of Smith’s ‘absolute advantages’,
but determine two fundamental processes of adjustments between, and within, countries.

First, inter-sectoral intra-national differences in technology gaps lead to a
tendency towards relative specialization 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, inter-sectoral gaps between countries would
lead to adjustments in world market shares. This other adjustment process is
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
inter-sectoral 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’).

Most of the trade literature nearly exclusively focuses upon the origins and
effects of ‘comparative advantages’. In the model we are thinking of revealed
comparative advantages which to some extent are only 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.

This analysis can easily be linked with a ‘Keynesian’ view of the determination
of the rates of macroeconomic activity of each economy. Unlike pure neo-classical
trade analysis – which generally imposes market-clearing conditions – and unlike
Ricardian trade models – which generally assume steady-state growth – such a
trade model allows, and indeed requires, changes in the level 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. One can thus illustrate how international gaps in
technology would define the boundaries of both ‘Ricardian’ processes of
adjustment in specialization and ‘Keynesian’ adjustment in the rate of
macroeconomic activity. From a dynamic point of view, it is the evolution in the innovative/imitative capabilities of each country which shapes the trend in the relative and absolute rates of growth of the tradable sector of each economy.

The normative implications of such an analysis are contrary to neo-classical or ‘new’ trade theory and are not straightforward. A discussion of normative issues, once out of the safe surroundings of market imperfections and anomalies, will indeed, as Nelson and Winter have warned: ‘be complex and messy. It is unlikely that one will be able to prove many sweeping normative theorems of the sort that are now contained in our advanced treatises and elementary texts.’ The much more complex framework does not allow one to draw the sort of elegant 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, the theoretical approach sketched out above does allow for a normative counterpart. It is possible to identify some general conditions under which conflicts between ‘allocative’ (which we will call ‘Ricardian’) efficiency and ‘dynamic’ efficiency (related to innovative and demand dynamism) could arise.

A first question regards the effect that the pattern of allocation – pulled by comparative advantages (and, thus, relative inter-sectoral profitabilities) on the basis of given technologies – will have on technological dynamism and long-term macroeconomic rates of activity. One can call the performance criterion related to innovative dynamism ‘Schumpeterian efficiency’ and that related to the maximum rate of growth consistent with the foreign balance constraint ‘growth’ or ‘Keynesian’ efficiency.

There appears to be nothing in the mechanism leading to ‘Ricardian’ efficiency that would also guarantee the fulfilment of the other criteria of efficiency. The easiest way to see the efficiency gains in a Ricardian world is to imagine that each nation, before trade, operates at full employment rates of activity and that there are no Keynesian adjustment processes linking absolute advantages, market shares and macroeconomics rates of activity in the transition from autarchy to trade. With all the other restrictive assumptions, one can easily see the full operation of the theorem of comparative advantage: each trading partner gains from trade since it gets more commodities of a certain kind from abroad than it would otherwise be able to manufacture domestically without forgoing any production and consumption of the commodities in which it specializes. It can also be seen how gains from trade of this kind are of a ‘once-and-for-all’, static nature.

Let us now relax both assumptions and ask what the effect of any given pattern of specialization might be upon the dynamics of the technological capabilities of each country, and what the outcome would be, in the short and long run, in terms of macroeconomic rates of activities whenever one allows for ‘Keynesian’ adjustments. It might be useful to recall the cumulative, (partly) appropriable and local nature of technological advances; the widespread existence of static and dynamic economies of scale; the influence that technological gaps between firms and between countries have upon the economic signals agents face; and the importance of country-specific and area-specific untraded interdependencies. These factors taken together allow for the possibility of significant trade-offs between statics and dynamics. If different commodities or sectors present significant differences in their ‘dynamic potential’ (in terms of economies of scale,
technical progress, possibilities of division of labour, learning-by-doing, etc.),
specializations which are efficient in terms of comparisons of given sets of input
coefficients may either generate in the long run virtuous or vicious circles of
technological backwardness.

This is more than a special case related to infant industries: it is the general
condition of an economic system whereby technological opportunities vary across
products and across sectors. Within each technology and each sector, the
 technological capabilities of each firm and each country are associated with the
actual process of production and innovation in the area. Thus, the mechanisms
regarding international specialization have a dynamic effect in that they also select
the areas where technical skills will be accumulated, (possibly) innovation
undertaken, economies of scale reaped and so on. However, the potential for these
effects is widely different between technologies and sectors. This is another aspect
of the irreversibility feature of economic processes: present allocative choices
influence the direction and rate of the future evolution of technological coefficients.
Whenever we abandon the idea of technology as a set of blueprints and we conceive
of technical progress as joint production with manufacturing, it is possible to
imagine an economic system which is dynamically better off (in terms of
productivity, innovativeness, etc.) if it evolves in disequilibrium six-a-cis
Ricardian conditions of allocative efficiency than otherwise.

It is rather easy to see how a trade-off between ‘allocative efficiency’ and
‘Schumpeterian efficiency’ can emerge. The patterns of specialization (with their
properties of Ricardian efficiency) are determined, for each country, by the relative
size of the sector-specific technology gaps (or leads). Whenever the gap is highest
in the most dynamic technologies (i.e. those characterized by the highest
technological opportunities), allocative efficiency will conflict directly with
Schumpeterian efficiency.

CONCLUSION

We would suggest that the likelihood of such trade-offs between Ricardian and
Schumpeterian efficiencies is proportional to the distance of each country from the
 technological frontier in the newest, most dynamic and most pervasive
technologies.

Technological leaders will tend to find the pattern of their inter-sectoral
profitability signals pointing in the direction of activities which also lead to the
highest demand growth and the highest potential of future product and process
innovations. Conversely, countries well behind the technological frontier may be
‘dynamically penalized’ by their present pattern of inter-sectoral allocative
efficiency. This property contributes, to the relative stability of the ‘pecking order’
between countries in terms of technological innovativeness and interactional
competitiveness, and the relatively ordered ways in which this ‘pecking order’
changes in the long term. The interactions between present economic signals,
patterns of specialization and dynamics of the sectoral technology gaps provides
the ground of cumulative processes.

Major changes in the interactional distribution of innovative activities and in the
international competitiveness of each economy can, however, be associated with
the emergence of new technological paradigms. This occurrence re-shapes the pattern of technological advantages or disadvantages between countries, often demands different organizational and institutional set-ups and sometimes presents a unique 'window of opportunity' (in Perez and Soete's words) for the emergence of new technological and economic leaders.

The foregoing arguments can be summarized in the following way. Markets characterized by decentralized decision-making fulfil two fundamental functions. First, they provide a mechanism of co-ordination between individual economic decisions and, in doing so, they reallocate resources in ways which under the conditions specified by the theory - present properties of efficiency. Second, whenever one allows technological progress to take place (with its features of search, uncertainty, etc.), markets provide an incentive to innovate through the possibility of private appropriation of some economic benefit stemming from technical progress itself.

As soon as these second functions of markets are taken into account, their efficiency properties become blurred and complicated to assess, even in a closed economy context: allocative efficiency in a static sense may conflict with dynamic efficiency in terms of incentives to technological progress. Overlapping with the 'Schumpeterian trade-off' of the closed-economy case, there is the possibility of a static versus dynamic trade-off originating from the pattern of economic signals in the international market. In a way, the open economy case induces a structural distortion on that pattern of signals which would have been generated under autarchy conditions. In doing so, they may either overrule the domestic 'Schumpeterian trade-offs' or amplify them. The hypothesis we suggested above is that this depends on the relative distance of each country vis-à-vis the technological frontier in those technological paradigms showing the highest opportunities of innovation and demand growth.

Any judgement on the regime of trade which should have preference 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.

Policy implications in the context of Europe 1992

It seems appropriate to conclude this introductory chapter with a couple of reflections on the technology trade relationship within the context of the completion by the end of 1992 of the large European internal market. For most EC member countries, this represents - both in its scale and scope - one of the major structural changes of the post-war period. 'Nineteen ninety-two' means less a change in absolute macroeconomic output and employment growth potential than a change in the potential for structural change; it implies a significant rationalization and increased efficiency potential resulting from the opening up of all sectors to intra-EC competition; it will see a significantly increased potential for labour, skill and capital mobility; and it presents the possibility of significant shifts in the location of regional growth. In terms of the potential for structural transformation, the nature and size of Europe's internal market completion is historically unprecedented.
The opening up to free trade or at least the harmonization of the large internal European market is likely to provide a major impetus to more rapid use and application of technological change, particularly in regions and sectors which have been at the periphery of the traditional European growth poles. It brings to the forefront in our previous analysis the importance of catching up, and possibly even shifts in technological competitiveness towards regions which possess both certain comparative cost advantages and benefit at the same time from certain minimum absolute cost advantages in terms, for example, of the right set of available infrastructure, educational provisions and institutional back-up. As a case in point one can think of Southern Europe and, in particular, of Spain and Portugal.

The specific EC market completion feature adds, indeed, three important dimensions to the traditional trade technology debate. First, the process of convergence likely to be set in motion as a result of the further harmonization of the internal EC market will in all likelihood lead to more rapid growth and more rapid diffusion of new technologies in catching-up countries or regions. In other words, there will probably be an increase in the variation in economic growth as between member countries and, as a consequence, also shifts in growth poles within the EC.

Second, and by the same token, some of the more ‘mature’ countries or regions, having benefited most from the liberalization and gains from trade in the 1960s and 1970s, will have a more specialized industrial structure, possibly more vulnerable to the further diffusion of, for example, new information technologies. This will depend fundamentally on the existing specialization structure. For some countries and regions this might amount to a reinforcing impact on a structure very much in line with such technologies; for others the opposite might be true. In so far as the international dimension is the logical extension of the regional dimension, the issue of the spatial impact of technological change within a large free trade zone is here the central point of analysis.

Third, the implications of this process of growth polarization for ‘national’ or regional employment growth and skill shortages are fundamental. On the one hand, because of intra-EC labour mobility, ‘national’ skill shortages or employment displacement might lose some of their meaning in favour of broad estimates at the supra-national EC level. On the other hand, local skill shortages and employment displacement become, even more clearly than before, major bottlenecks for the rapid diffusion and application of new technologies and the emergence of new growth poles. The likely structural adjustment impact of the harmonization of the internal European market, and its possible ‘accelerating’ impact on the diffusion of new technologies, adds in other words an interesting ‘new’ dimension to strategic ‘national’ trade or industrial policy.

Reaping the benefits and advantages from technological change and the further harmonization of the internal EC market is a crucial national challenge for each individual nation, with significant implications for its international competitiveness; though the scope for doing so through traditional national industrial policy means will have by and large disappeared. What emerges as far more crucial though is the establishment and maintenance at the regional level of a sufficient level of ‘absolute’ advantage conditions both in terms of educational and the wide variety of infrastructural provisions.