Technology and Competitiveness

by

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Abstract

This paper reviews the literature on technology and competitiveness. First, the concept of the international competitiveness of a country, and various theoretical approaches on the relationship between trade and growth, are discussed. Then a number of empirical studies of the impact of technology (as evidenced by R&D, patents, etc.) on exports are examined. The final section summarizes the evidence and considers the lessons for policy.

Note

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1. Introduction

"Technology" and "competitiveness" are two of the most popular buzz-words of our time. Increasingly policy makers on both sides of the Atlantic link the two. But what do we really mean when we talk about the international competitiveness of a country? And what does technology have to do with it? Is there a theory behind this link? What about the empirical evidence? This paper addresses these questions from a long-run perspective.[2]

2. The competitiveness issue

Many concepts that economists use in professional discourse are virtually unknown to the broader public. For instance, who has heard about "Ricardian equivalence" (and knows what it means)? Probably not many outside the inner circles. Not so with "international competitiveness". Almost everybody seems to know something - and even have an opinion - about the international competitiveness of their country.

How can that be? The reason is simple. It is not a concept invented by theoreticians, but by practical people close to the policy making process. Although widely used, some theoreticians detest it. For instance, the American economist Paul Krugman has gone so far as to talk about the concern for the international competitiveness of a country as " dangerous obsession" (Krugman 1994). This led to a vivid debate in the American journal Foreign Affairs in 1994.

[2] Hence, the paper does not deal with the typical short-run variations in costs, prices etc. that people sometimes associate with changes in competitiveness.

What is it with this issue that makes it attract so much attention, not to say emotion? Let us start by stating a few simple facts regarding the concept and its use. First, it is applied at several levels. What has been the prime focus of the debate, and what we will focus on here, is its application to a country. Second, it is a relative term. What is of interest is not your absolute performance, however that may be defined, but how well you do relative to other countries. Some dislike this comparative perspective. But, after all, this is a perspective that we find in nearly all aspects of social life, work, sports, business etc., among individuals as well as collectives. So why not at the level of countries? I see no compelling reason against its use.[3] Third, when applied to a country, it has a double meaning, it relates both to the economic well-being of its citizens as well as the nation's trade performance.[4] The underlying assumption, then, is that these things are intimately related. This is perhaps not so controversial in itself, but the nature and cause of this relationship may be. In the next section we discuss this in more detail.

However, the recent controversy seems to have little to do with these points. Rather, what Krugman is aiming his criticism at is the common American attitude of blaming shortcomings on foreigners (and acting accordingly). If American producers do not meet the standards of international competition, then this failure is more or less automatically explained by unfair practice by foreign competitors and/or governments and Congress is lobbied for protection. Although the tendency to blame others for one's own failures may be universal, this has never been a real option in smaller economies. The reason is simple; if one depends on export markets for a large share of what one produces, the very least one would do is to give other governments an incentive to impose import restrictions. By and large, this has also been the situation for most medium-sized developed countries such as, for instance, the UK. However, in a large country such as the US, in which about ninety per cent of the output is sold

[3] Dunn (1994) and Moran (1996) both defend this comparative perspective by pointing to the relationship between economic performance and power.

[4] There are many definitions around, most of which reflect this "double meaning" in one way or another. A typical example is the following: Competitiveness is "the degree to which, under open market conditions, a country can produce goods and services that meet the test of foreign competition while simultaneously maintaining and expanding domestic real

at the domestic market, foreign retaliation may not be seen as a real threat. Arguably, this may also hold for the European Union when considered as a whole. I agree that the tendency to blame your own failures on others is unhealthy. Rather what one should focus on is one's own performance, on which domestic well-being ultimately depends, as Krugman correctly points out. But if there is an obsession here, it is not with competitiveness per se, but with trade policy/protectionist politics.

Another pitfall in this area has been to equate competitiveness solely with indicators of relative unit costs or prices. This was sometimes justified by the absence of data on so-called "non-price" factors. Kaldor (1978) was among the first to point out the seriousness of omitting such factors. He showed for a number of countries that, over the long term, market shares for exports and relative unit costs or prices tend to move together, i.e., that growing market shares and increasing relative costs or prices went hand in hand (the so-called "Kaldor paradox"). This was, of course, the opposite of what one would have expected from the simplistic, though at the time widely diffused, approach which focused exclusively on the (assumedly negative) impact of increasing relative costs or prices on market shares.

Table 1 updates and extends Kaldor's investigation to the more recent 1978-1994 period. The countries included are the twelve largest exporters in the world (in the 1990s). The table shows that Kaldor's paradox also holds good for this more recent period. Thus, growing market shares and growing relative unit labour cost tend to be positively associated (rather than the other way around as commonly assumed). The table also includes data for two other variables often invoked in discussions of competitiveness; productivity growth (proxied growth of GDP per capita) and the increases in research and development (R&D) expenditures (as a share of GDP). The latter may be interpreted as a rough indicator of change in technological capability.[5] It

income" (OECD 1992, p. 237). Porter (1990, Ch. 1) and Reinert (1995) provide an extended discussion.

[5] Changes in R&D expenditure as a share of GDP may reflect both general changes (common to all industries) and changes in the industrial composition. Differences in R&D, as percentage of GDP or production, are known to be much greater across industries than across countries (within an industry). Large changes in R&D expenditure as a percentage

turns out that the growth of market share is strongly positively correlated with both. Hence, as a rule, countries that gain market share also display faster productivity growth and increase technological capability more than other countries.

Table 1.The Kaldor-paradox re-examined, 12 industrialized countries, 1978-1994

	Growth in market share for exports [a)]	Growth in relative unit labour cost [a)]	Growth in GDP per capita at constant prices [a)]	Change in R&D as a share of GDP [b)]
USA	0.08	-1.17	1.36	0.24
Japan	0.95	0.82	2.94	1.10
Germany	-1.03	1.62	1.65	0.23
France	-0.98	-0.18	1.36	0.54
Italy	-0.16	-1.13	2.00	0.59
United Kingdom	-0.89	0.81	1.57	-0.01
Canada	-0.10	-0.38	0.97	0.36
Belgium	-0.89 [c)]	-2.85 [c)]	1.70	0.31
Netherlands	-1.53	-1.60	1.23	0.13
Korea	4.85	1.89	6.33 [c)]	1.16
Taiwan	4.68	3.77	5.94 [d)]	1.13
Hongkong	8.36	2.58	5.35 [c)]	NA
Regression on growth in market share [e)]	slope	1.17	1.43	4.48
		(0.36)	(0.21)	(0.94)
	R^2	0.52	0.82	0.71

Notes:
a) Annual rate of growth
b) Difference between 1992 and 1979 levels of R&D as a share of GDP
c) 1978-1992
d) 1978-1991
e) Estimated by OLS with constant term (not reported), standard deviation in brackets. 12 observations except for R&D (11 observations)

Sources: OECD (gdp per capita and relative unit labour cost), IMF (merchandise exports) and EMF/IMD-World Economic Forum and national sources (R&D). Belgium includes Luxembourg (except for exports).

The facts are reasonably clear. But how are they to be explained?

of GDP, such as those reported for Korea and Taiwan, are therefore likely to reflect changes in those countries' industrial composition from low R&D to high R&D industries.

3. Technology, trade and the wealth of nations

Until recently the competitiveness issue was mostly neglected by neo-classical theoreticians. The single most important reason for this was, perhaps, that neo-classical theory did not attach much importance to trade as a growth-promoting factor.[6] Following the standard neo-classical approach to growth it did not really matter whether you sold your goods at home or abroad. It is true that the so-called factor proportion theory postulated that there were some gains from trade through increased specialization in sectors using intensively the factors with which countries were relatively well endowed. However, these gains were essentially of an once and for all nature. Moreover, empirical work on trade based on this perspective indicated that they were rather small (Robson 1987).

The traditional neo-classical view on growth and trade rested on very restrictive assumptions. In particular, it neglected demand as a source of growth, it did not allow for economies of scale and it assumed away technological differences across countries. Alternative views on the subject relax one or more of these assumptions.

Keynesian theories, attempting to come to grips with the growth of open economies, came to focus on the demand for exports as a source of growth in its own right. While domestic demand was assumed to be more or less endogenous, export demand was seen as an autonomous force that could propel growth (through various multipliers). Anything that raised export demand would also raise growth (Beckerman 1962, Kaldor 1970).

A problem with this perspective was that no allowance was made for the need to balance trade, if not in the short so at least in the longer term. It was thus possible that projections based on this approach might give growth paths that were unsustainable

[6] For an overview of the literature on trade and growth, see Dowrick (1996).

because they implied ever-increasing accumulation of reserves or foreign debt. This could be remedied by introducing a balance of trade constraint and assuming, for instance, that governments would modify fiscal and monetary policies towards this end. Such a model was suggested by Thirlwall (1979). In this model the growth of an open economy was shown to depend on growth of international trade, on changes in relative prices (price competitiveness) and on the ratio of the income elasticity of exports to that of imports.[7] Thus, assuming everything else constant, the higher the income elasticity of exports relative to that of imports, the higher the rate of growth would be, and vice versa. Using estimates from Houthakker and Magee (1969), Thirlwall claimed that this simple model gave a remarkably good approximation to the growth experience of many countries in the first half of the postwar period, even when the impact of changing relative prices was ignored. This was taken as a demonstration of the importance of so-called non-price factors, which the estimated income elasticities were assumed to reflect (and also the relatively modest impact of price factors). Such results were, of course, consistent with the seemingly paradoxical findings of Kaldor (1978).

Thirlwall's model and its explanatory power have been the subject of considerable controversy, a full account of that would require a paper of its own, if not a whole book (as was suggested by McCombie 1992).[8] Table 2 updates Thirlwall's calculations[9] to the more recent 1979-1993 period. An estimate for the preceding period (1960-1979) is also provided.

[7] The income elasticity of exports is the growth in exports resulting from a 1% increase in world demand, holding relative prices constant (and ignoring cyclical factors). Similarly for imports.

[8] This book has since been published (McCombie and Thirlwall, 1994).

[9] The estimates reported here are based on equation (8) in Thirlwall (1979), disregarding the price term, since, following McCombie and Thirlwall (1994, p. 341), this is the most appropriate specification.

Table 2. Thirlwall's law re-examined, 9 industrialized countries, 1979-1993

	Income elasticity of exports to that of imports [a)]	Actual growth 1960-1979	Predicted growth [b)] 1960-1979	Actual growth 1979-1993	Predicted growth [b)] 1979-1993
USA	0.66	3.46	2.92	2.27	1.41
Japan	2.89	7.71	12.84	3.57	6.20
Germany	1.16	3.70	5.14	2.11	2.48
France	0.92	4.58	4.10	1.80	1.98
Italy	1.35	4.79	5.99	1.97	2.89
United Kingdom	0.52	2.59	2.30	1.71	1.11
Canada	1.18	5.02	5.23	2.27	2.52
Belgium	0.94	4.05	4.20	1.83	2.03
Netherlands	0.99	4.14	4.43	1.79	2.14
Coefficient of variation	0.55	0.30	0.55	0.25	0.55
Regression on actual growth [c)]	slope	0.44 (0.05)		0.35 (0.06)	
	R^2	0.90		0.81	

Notes:
a) Estimate of income elasticities, based on data for the period 1951-1966, from Houthakker and Magee (1969).
b) Predicted growth is calculated as the ratio of the income elasticity of exports to that of imports multiplied by the average growth of the countries in our sample.
c) Estimated by OLS with constant term (not reported), standard deviation in brackets.

Source(GDP): OECD

A cursory look at the data reveals that the model reproduces correctly some of the qualitative features of the postwar growth experience (such as the relatively rapid growth of Japan and the slow growth of the UK). However, the model systematically overpredicts these differences, and this tendency becomes more manifest through time (as shown by the coefficient of variation). None of this is necessarily surprising. First, the model is based on the assumption of balanced trade, which might not hold for all countries.[10] Second, price effects are ignored altogether, which is, it has to be said, a quite drastic simplification. Third, and perhaps most important, the non-price factors, which the estimated income elasticities are assumed to reflect, are themselves likely to

[10] This is not so restrictive as it seems, since the formal model actually accomodates a constant surplus or deficit (as a percentage of exports or imports).

change through time. Thus, in the long run, these elasticities should be considered as variables rather than as exogenously given constants.[11]

This raises the question of how these non-price factors can be identified and measured. There are, of course, many factors that could be considered potentially relevant, and it is beyond the purpose of this paper to discuss all of these in great detail.[12] One prime candidate, though, is differences in technological capabilities, as originally suggested by Nicholas Kaldor (1981, p. 603):

"Basically in a growing world economy the growth of exports is mainly to be explained by the income elasticity of foreign countries for a country's products; but it is a matter of the innovative ability and adaptive capacity of its manufacturers whether this income elasticity will tend to be large or small."

A natural conclusion from this would be to include indicators of technological competitiveness (or innovative ability and adaptive capacity) directly in the equations for exports and imports. This was the route taken by Fagerberg (1988).[13] He related changes in the market shares of a country at home and abroad to the change in its technological capacity (whether resulting from innovation or from exploiting the potential for imitation). The growth in productive capacity, proxied by gross investment in physical capital, changing relative unit labour costs and growth of demand were also taken into account. The empirical results, based on data for 15 OECD countries from the early 1960s to the early 1980s, generally confirmed the importance of growth in technological and productive capacity for competitiveness,[14]

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[11] Several studies for the UK conclude that these elasticities (and/or the underlying trends that they reflect) are not stable through time (Landesmann and Snell 1989, Anderton 1992, Blake and Pain 1994).

[12] A more general discussion of the impact of non-price factors on trade may be found in McCombie and Thirlwall (1994, Ch.4).

[13] Fagerberg also departed from the Thirlwall framework by introducing a direct test of the assumed equality of the actual growth rate and one that would be consistent with balanced trade. He found that this was a reasonable approximation for most (though not all) countries. The exceptions were the USA, the printer of world money, and Norway, which during this period started to produce oil on its continental shelf.

[14] McCombie and Thirlwall (1994) argue that these results depend to some extent on the inclusion of Japan in the data set.

while the impact of cost factors was found to be relatively marginal. These results provided a reasonable explanation of the so-called Kaldor paradox (Kaldor 1978).

The idea that in capitalist reality it is technological, rather than price competition, that matters most, is not a new one. This thesis had been forcefully argued by Schumpeter (1934, 1939, 1943) and by Marx before him. But in the theoretical universe of the neo-classical theorist of the 1950s and 1960s (that of so-called perfect competition) this was not an idea that could be easily accommodated. Hence, it tended to be ignored. However, the idea popped up now and then, in particular when researchers encountered empirical phenomena that the established theory could not explain. Such an incidence occurred in the 1950s when Leontief (1954) provided evidence that the specialization pattern of the USA in international trade seemed to deviate from what neo-classical theory predicted. In particular it did not seem to rest in capital-intensive industry as would be expected. Several authors responded to this by suggesting that the real competitive strength of US industry lay not in its capital abundance, but its superior technological capability. This led to the formulation of the so-called neo-technological trade theories of the 1960s, which emphasized the importance of cross-country differences in technological capability and their impact on trade (Posner 1961, Vernon 1966 and others, for an overview see Dosi and Soete 1988).

A particularly clear and influential account of the neo-technological perspective was the one given by Posner (1961). The essence of his reasoning can be captured by a two-country model, in which one country is more innovative than the other (and consequently has a technological lead), while the other (the technological laggard) relies more on imitation. New technologies emerge in the technologically leading country, which for a period enjoys a temporary monopoly. However, in the course of time, the technological laggard will learn to cope with these technologies as well, and competition between producers from the two countries will arise. Generally, the level of income will be higher in the leading country, with the size of the income gap depending on size of the technological gap (or the time needed for the lagging country to imitate the innovations of the leader).

Formal models based on this logic started to emerge in the 1970s. These models - so-called North-South models[15] - envisaged an innovating North, paying high wages, and an imitating South exploiting cost advantages (low wages), with the wage gap between North and South depending on the balance between innovation (North) and imitation (South). Assuming everything else constant, technological catch-up (increased speed of imitation) by the South would reduce the wage gap and, under certain assumptions, also Northern welfare. To prevent this from happening, Northern industrialists were left with no other choice than to increase the speed of innovation. Krugman (1979, p. 262), one of the theoretical contributors in this area, formulated this vividly as follows: " Like Alice and the Red Queen, the developed region has to keep running to stay in the same place."

Recently, there has been a surge of new formal contributions in this area. While the first generation of North-South models considered innovation in the North as exogenous, the most recent modelling efforts have sought to endogenize innovation, hence the terms "endogenous" or "new" growth theory.[16] There are basically two strands in this literature, one that analyses technological progress as learning by doing (Romer 1986, Lucas 1988), and another that emphasizes investments in R&D (Romer 1990, Grossman and Helpman 1991). In both cases long-run growth is explained by (a) private incentives to investments in activities that lead to innovation (learning) and (b) the spillovers from this process on future investments of this kind.

In the first strand it is pertinent to mention the contribution by Lucas (1988). He assumes large differences across sectors in the scope for technological progress (learning). Hence, countries that specialize in the technologically progressive (high-tech) industries may experience faster growth than those which do not. Because of the

[15] For an overview, see Goglio (1991).

[16] The following does not attempt to survey "new growth theory", just point to some contributions that are important in the present context. A good , condensed overview is provided by Verspagen (1992).

cumulative character of technological progress, existing patterns of specialization will tend to be reinforced through time. Thus, market forces may actually strengthen a specialization pattern that implies slow growth (a low growth trap). In this situation, Lucas argues, it may actually pay off for a country to change its pattern of specialization by a combination of subsidies and protection.

The most interesting contributions from the perspective of this paper belong, perhaps, to the class of models that emphasizes the importance of R&D and spillovers for growth and trade (see Grossman and Helpman 1991). Countries that devote a large share of their resources to R&D, and countries with large domestic markets, will - according to this perspective - be more likely than others to specialize in high-tech industries and may display faster growth. However, the outcome also depends on the geographical reach of spillovers.[17] If, for instance, spillovers are national rather than global in scope, a "lock in" situation may occur, where small initial differences lead to a divergence in specialization patterns and growth. As in the Lucas model above, this is a situation where policy interventions may have a large impact. To the extent that presence in foreign markets is required to benefit from technology flows, trade may enhance growth (Coe and Helpman 1995).

There is now, therefore, a quite large (and diverse) literature suggesting that the link between technology, competitiveness and growth is an important one. In the older Keynesian exports, exports were considered exogenous and growth endogenous. Hence according to that approach, the causation runs from trade to growth. At a deeper level the exogenous factors are those impacting on trade performance, in particular non-price factors, among which technology has been recognized as a prime

[17] Little is known for sure on the geographical reach of spillovers. Some studies suggest that these often are rather local in nature (Jaffe 1989, Jaffe et al. 1993), i.e., that proximity is an important factor. There are also some evidence indicating that technology flows less freely across than within countries (Sjöholm 1996). However, Nelson and Wright (1992) and Nadiri (1993) both argue that international flows of technology have accelerated up in recent years, and that the main vehicle for this is the transnational corporation (TNC), i.e., that spillovers are increasingly becoming global. Others stress the continuing ties between TNCs and their home countries (Patel and Pavitt 1991). See also Globerman (1996).

candidate. Models that allow for technology to play a role in global competition point to the balance between innovation and imitation as the main force explaining both trade and growth. However, in reality innovation and imitation are not exogenous, but depend on factors such as incentives, skills and the environment in which they are carried out. Recent modelling efforts in this area attempt to push the analysis further by incorporating some of these aspects.

4. Technology and exports

Empirically, analysts have tried to highlight the relation between competitiveness and technology by regressing a measure of export performance on a technology variable and other variables that were deemed relevant for the analysis. Generally, the relation is the following:

(1) $X = f(T, O)$,

where X is a measure of export performance, T is a technology proxy and O is a set of other variables. The following paragraph discuss the main results from this work (a more comprehensive overview may be found in Wakelin 1995). Similar analyses have also been carried out with imports or the performance on the domestic market as the dependent variable, and yielded roughly similar results.[18] Trade in services, on the other hand, has been completely neglected.

The technology variables used in these analyses can be divided in technology- input and technology-output measures (Soete 1981). Among the former, the most popular choice is R&D spending, but scientific personnel has also been used. Technology output measures include patent-based measures (Soete 1981), innovation counts

[18] See Hughes (1986) and Buxton et al. (1994) for the UK and Fagerberg (1988) for a group of OECD countries.

(Greenhalgh 1990, Greenhalgh et al. 1994) and various measures of productivity (Milberg 1991, Wolff 1995, 1996). Composite measures combining two or more of these alternatives have also been suggested (Aquino 1981, Fagerberg 1988).

None of these measures is perfect. For instance, innovations made by engineers as a result of learning by doing, using etc. do not have a clearcut relationship with R&D as normally recorded (Patel and Pavitt 1994). The propensity to patent is known to vary widely across industries. Some industries do much R&D, without patenting a lot, and others do the reverse (Pavitt 1982). Productivity measures have at best an indirect relationship with innovation. However, at the national level, R&D, patents and productivity based measures are closely correlated (Fagerberg 1987).[19]

The first analyses of this kind were undertaken in the late 1960s following the advent of the neo-technological trade theories, and focused on US export performance, using data for a cross-section of industries. Initial results on US data seemed to support the emphasis in these theories on the importance of R&D for export performance (Gruber et al. 1967). Later Sveikauskas (1983), in a very thorough study, convincingly showed that the competitiveness of US exporters rested on R&D and on innovation (rather than the supply of skilled labour or other factors). More recently, much of the applied literature in this area has focused on British evidence. Hughes (1986) demonstrated the importance of both R&D (absolute and relative to foreign competitors) and skilled labour for British exports.[20] A strong relationship between R&D and the international competitiveness of British industry has also been reported by Buxton et al. (1994) . Greenhalgh (1990) and Greenhalgh et al. (1994), using different data and methods, showed the importance of "home grown" innovation for British trade performance. There are also some scant evidence from other countries indicating that indigenous

[19] For a discussion of indicators and measurement, see Archibugi (1992) and Patel and Pavitt (1995).

[20] She also found support for a simultaneous relationship between exports and R&D, consistent with the Kaldorian ideas of "cumulative causation" and "virtuous and vicious circles"(Kaldor 1981).

R&D and innovation may have an influence on trade performance (even though the country as such is not specialized in high-tech industries).[21]

However, analyses for single countries across industries, interesting as they may be, fail to test for possible differences across sectors in the impact of technology and other variables. The latter may be investigated applying equation (1) to a cross-section of countries for single industries. Such analyses typically use data for all or most OECD countries (Lacroix and Scheuer 1976, Soete 1981, Dosi and Soete 1983 and Fagerberg 1995). There are also some studies that pool cross-sectional and time-series data, but then for a smaller number for countries (Magnier and Toujas-Bernate 1994 and Amable and Verspagen 1995). As these studies use different sectorial classifications and include different variables, the results are not directly comparable. However, to facilitate comparison results from a number of studies are presented in one common table (Table 3). Preparation of this table has involved a considerable element of judgment, and the table should only be read as an indication of the state of the art in this area. Readers interested in particular studies or industries are urged to consult the original sources.

[21] Lundberg (1992) applies Hughes's model to Swedish evidence and reaches similar results. For an analysis of the impact of R&D efforts on Australian foreign trade, see Engelbrecht (1992).

Table 3. Impact of technology and other factors on trade performance

	R&D intensity	Technology						Price/cost			Investment					Scale	
	Percent of production, 1985	R&D			Patents												
		L	F	M	S	F	A	F	M	A	L	S	F	M	A	S	F
Aerospace	20	-	-	x	x	-	-	-	x	-	-	-	-	(-)	x	-	x
Computers	10		-	x	x	-	x	-	x	-		-	-	x	x	-	x
Electronics	8	X	x	-	x		-	x[4)]	x	-	-	-	-	x	-	-	x[4)]
Instruments	6		x	-	x	x	x	-	x	x		-	-	x	-	-	-
Electrical machinery	3			-	x	x	-	x	-	-		-	-	-	-	-	-
Non-electrical machinery	2	x		x	x	x	x	x[2)]	-	-	-	-	-	-	-	x/-	x[3)]
Cars	3		-	x	x	-	x	-	-	-		-	-	-	(-)	x	x
Other transport	3	X		-			-		x	-	-			-	-		
Ships	0		(-)		-	-	-	-		-		-	x		-	-	-
Drugs	9	x		-	x	x	x	x	x	-	-	-	(-)	x	-	-	(-)
Industrial chemicals	3	x	x[1)]	x	x		x	x[1)]	x	x	-	-	-[1)]	-	-	x	-[1)]
Plastics	1	x	x	-	x		x	x	-	x	-	x	-	x	-	x	-
Petroleum refining	1	-		-	-				x		-	x		-		-	
Ferrous metals	1		-	-	x	-	x	-	x	x		-	-	-	-	x	-
Non-ferrous metals	1	X	-	-	x	-	-	-	x	-	-	x	-	-	-	-	(-)
Metal products	1			x	x	x	-	x	x	x		-	-	-	-	x	-
Stone, glass & clay	1	-		-	x		x		-	x	-	-		-	(-)	x	
Wood & wood products	0	-		x			x		x	x	-			-	-		
Paper	0	x	-	x		-		-	x		-		-	-			-
Textiles, clothing	0	-	-	x	-	-	x	x	x	x	-	-	-	-	-	x	-
Food & drinks	0	x		x	-		x		x	x	-	-		-	-	-	

Symbols:
x = Significant, correct sign
x/- = Conflicting evidence
- = Not significant
(-) = Significant, incorrect sign
Blank = Not included

Notes:
1) Organic chemicals
2) Special machinery
3) Power generating machinery
4) Semiconductors

Sources:
R&D intensity; Fagerberg (1996)
L: Lacroix and Scheuer (1976); 15 sectors/12-17 countries, 1968
F: Fagerberg (1995); 28 sectors/19 countries, 1960-1983 (average values)
M: Magnier and Toujas-Bernate (1994); 20 sectors/5 countries, 1980-1987
S: Soete (1981); 40 sectors/22 countries, 1977
A: Amable and Verspagen (1995), 18 sectors/5 countries, 1970-1991

Generally, the results of these studies support the hypothesis of a positive relation between technological activity and export performance for a large number of industries. The most consistent results supporting such a relationship are found for the chemical (drugs, industrial chemicals and plastics) and machinery industries. Among the latter the evidence is particularly strong for non-electrical machinery, a very broad category covering a wide range of specialized and general machinery, as well as for instruments and computers. There is also quite strong evidence linking technology and exports in the car industry. However, the evidence of such a link is not confined to industries commonly regarded as high-tech (or R&D-intensive), although the evidence generally is stronger for these industries. Among the less high-tech industries for which technological competition appears important, metal products and food and drinks may be mentioned. It is noteworthy that there is only one industry (petroleum refining) for which there is no evidence whatsoever of a positive impact of technology on export performance.

On the importance of price competition, the evidence is more mixed. Price competition appears to be important in chemicals, for which also technology was found to be an important factor. For machinery and transport equipment the evidence of price competition is rather weak, with the exception of electrical machinery (which includes many consumer products) and electronics (semiconductors). As might be expected, price competition appears to be of importance in many low-tech industries, such as textiles and clothing. The investment variable - usually measured per worker - failed to have a significant impact in all but a few cases.

Some studies also include a variable assumed to reflect the size of the country or its domestic market. But – with the exception of Fagerberg (1995) – the reported results are difficult to assess, since several variables included in these tests to some extent already reflect scale factors. Fagerberg (1995) found scale factors to be important in a few industries only, covering around one-fifth of total OECD trade. The findings suggested that a distinction should be made between technology (including R&D) as an input in the process of production and as the most decisive factor in the process of

global competition. Industries such as aircraft, computers and - to a lesser extent - cars are clearly among the most R&D intensive, but according to this study, comparative advantage in these industries is determined by access to a large domestic market rather than by differences between countries in R&D efforts.[22]

Until recently, most studies have focused on the impact of direct R&D and innovation by firms on exports. The impact of technology flows from other firms, industries and countries, though potentially important according to recent theorizing in this area, have received far less attention. The reason is, of course, that little is known about these flows. However, Fagerberg (1996), in a study based on data for ten OECD countries and twenty industries in the mid 1980s, included both direct R&D and R&D acquired indirectly through purchase of capital goods and intermediary products from domestic and foreign sources as possible determinants of exports. The results from that study indicate that although both direct and indirect R&D have a significant, positive impact on export performance, the impact (i.e., the estimated elasticity) of the latter is about twice that of the former.[23] Indirect R&D from domestic sources appeared more conducive to competitiveness than indirect R&D from abroad. This naturally favours firms in large countries, since these source a larger share of their inputs domestically. Also the impact of direct R&D on exports was found to be larger in large countries, consistent with the predictions of “new growth theory”, and with the fact that the firms in large countries actually devote a much larger share of their resources to R&D than firms in small countries. Yet, R&D appears as a very potent factor for competitiveness in small countries as well, since the total impact on exports of an investment in R&D was found to exceed the impact of an investment of similar size in physical capital in both large and small economies.

[22] Van Hulst et al. (1991) also found that technology variables had little explanatory power in some "very high-tech" industries.

[23] To the best of my knowledge, there are no other studies on this subject. But studies of indirect R&D on productivity have arrived at estimates of roughly the same order of magnitude (see Nadiri 1993).

Market size is only one among several factors that may contribute to a different development across countries. Exploiting the time series dimension of the data, several authors have looked at the extent to which impact of specific variables differs across countries (parameter constancy, speed of adjustment etc.). For instance, Magnier and Toujas-Bernate (1994) find that R&D has a much larger impact in Japan than elsewhere. Amable and Verspagen (1995), using patents instead of R&D, point to the USA, not Japan, as the country in which technology has the largest impact on exports. However, they do find a much higher speed of adjustment in Japan than elsewhere. This leads them to conclude "that the general institutional arrangements in Japan may substantially differ from those in Germany, the USA, the UK or Italy" (Amable and Verspagen 1995, p. 201). Pain and Wakelin (1996), analysing the aggregate export performance of fourteen countries in the 1970s and 1980s, report that both prices and technology (measured by patents) matter for most countries. But, according to this study, the evidence of a positive impact of technological acttivity on export performance is weaker for the USA than for most other economies. Moreover, the estimated impact of technology on Japanese exports is not particularly large. In fact, according to the authors, France is the country for which technology matters most for trade. Thus, although several studies indicate that there may be some heterogeneity among countries in the way technology and other variables affect competitiveness, the present evidence does not allow us to draw strong conclusions about its precise nature.

5. Lessons

The notion "the international competitiveness of a country" has attracted much attention, not to say emotion, lately. However, the basic idea behind it is sound and simple; people do care about how well they do compared to others, individually as well as collectively. A consensus definition of international competitiveness might perhaps be that it reflects the ability of a country to secure a high standard of living for its citizens, relatively to the citizens of other countries, now and in the future. At the same time it is usually assumed that the concept is related to trade. This is perhaps not so controversial in itself, what is at stake is rather the direction of causality. A number

of arguments have been considered, focusing on the demand as well as on the supply side. While growth obviously affects trade, there are also good reasons to assume a feedback from trade on growth, i.e., that causation goes both ways. Thus, it makes considerable sense to look at indicators reflecting both income (or productivity) and trade when assessing international competitiveness.

While there may be many factors impacting on trade in the short term, this paper has focused on the long term, and on the role of technology in particular since theoretical work in this area increasingly suggests that technology has an impact on trade performance. There is also a large and growing applied literature on the subject. Three central findings may be noted. First, R&D and innovation play an important role in many industries, not only those that are commonly regarded as high-tech (although the impact is perhaps more pronounced in the latter). Second, in some "very high tech" industries, competitiveness seems to be heavily affected by the size of the domestic market. (This is true for Aerospace, but may also apply to other industries). Thus, while R&D and innovation may matter for competitiveness in both large and small countries, the latter should be careful not to use the specialization pattern of the former as a kind of yardstick of success. Third, R&D does not only matter for the firm or sector of origin, but spills over to other firms and sectors, and these spillovers are at least as important as the direct effects. This is, of course, an argument for public support to R&D in private firms, since under such circumstances there tends to be underinvestment in R&D. To the extent that national borders act as a barrier to technology flows (as some research suggests), firms in small countries may find themselves at a disadvantage. For Europe this points to need to speed up cross-country technology flows through appropriate policies.

A concern for international competitiveness is sometimes seen as a support for a zero-sum game. But this is not at all a necessary effect. If it is recognized that the most efficient way to enhance competitiveness in the longer term is to support innovation and diffusion of technology, this may actually lead to higher growth worldwide, and

higher welfare all around. This is especially so since countries traditionally specialize in different areas and devote their resources to R&D and innovation accordingly. [24]

[24] The resulting specialization patterns are surprisingly sticky (for evidence, see Amendola et al. 1992, Papagni 1992 and Archibugi and Pianta 1994).

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