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The policy implications of the globalisation of innovation

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Abstract

The paper develops a taxonomy of the globalisation of innovation based on three categories: (a) the international exploitation of technology produced on a national basis; (b) the global generation of innovations; (c) the global technological collaborations. The most evident changes implied by the increasing globalisation of innovation and technology are the tougher and increased competition and the greater collaboration between actors, both across and within national boundaries. The advantages, just as the costs, of these tendencies can be substantial, leading to a higher risk of 'winners and losers'. The paper analyses the different impact that each category might have on the economic and innovative performance of countries and regions, with the aim of defining the implications for national policies. It is suggested that public policies play a different role in each of the three processes of the globalisation of innovation and that a single strategy does not exist, neither from a firm's nor from a government's perspective. The paper emphasis that none of the three categories in this taxonomy renders national policy obsolete. On the contrary, public policies are necessary on a far wider range than those currently implemented in the majority of countries.

Keywords: Globalisation of innovation; Winners; Losers; Multinationals

1. Introduction

Globalisation is not a single phenomenon, but a catch-all concept to describe a wide range of forces intensifying transnationals issues. [2] The importance of globalisation is currently the focus of a vivid controversy. On one hand, there are those who main-

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[2] Globalisation can be defined very differently by different social scientists. Streeten (1996) has, half in the jest, collected the various definitions found in the literature. International economists would tend to favour the quantitative level of integration between different countries and/or regions. For our purposes, we have applied a wider definition of globalisation as provided by Giddens (1990) (p. 64): ''the intensification of worldwide social relations which link distant localities in such a way that local happenings are shaped by events occurring miles away and vice versa.''

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tain that globalisation has effectively contaminated the greater part of economic life (Ohmae, 1990; Chesnais, 1994; Barnet and Cavanagh, 1994; Brecher and Costello, 1995; Perraton et al., 1997); on the other hand, there are those who are still sceptical about its importance in quantitative terms (Ruigrok and van Tulder, 1995; Michie and Grieve Smith, 1995; Hirst and Thompson, 1996). However, the terms of the debate are often unclear as three issues, although related but which should be kept separated, are not well-clarified.

The first is to establish the importance of global forces in social life (Does globalisation exist or not?). This requires the identification of the different types of globalisation and an estimate of their weight according to geographical location, industrial sectors and social groupings. The second refers to the value judgement attributable to globalisation (Is a global society a good or a bad thing?). Answers to this type of question can only be given by clarifying the actors of reference. Finally, the third issue refers to the viability of national policies enabling the modification of the inertial tendencies produced by globalisation (Are there any policies which can regulate globalisation?). As these policies are mainly implemented at a national level, the debate on globalisation must necessarily be judged with reference to the effectiveness of the policies implemented by national governments.

In this paper, we attempt to critically assess the concept of globalisation as applied to innovation. Our intention is to define its implications for national policies. In Section 2, we present a taxonomy of the globalisation of innovation based on three categories: international exploitation, global generation and global collaboration on innovation. This taxonomy, which has already appeared in previous work (Archibugi and Michie, 1995, 1997a), is considered here in the light of the debate it has triggered, as we believe that it constitutes a useful filter through which to interpret not only the size of the phenomenon (see the works of Iammarino and Michie, 1997; Archibugi and Iammarino, 1997), but also the bearing of public policies on each of the ongoing processes. In fact, in the following two sections, we shall analyse the impact that each category of the globalisation of innovation might have for single countries, with the specific intention of exploring the public policy implications. In Section 5, we identify some directions for further research on the debated topic.

2. A taxonomy of the globalisation of innovation

During the past few years, too many heterogeneous phenomena have been included in the term 'globalisation of innovation' and this has made the concept's explanatory power loose its potency. Thus we have attempted (Archibugi and Michie, 1995, 1997a) to escape from the maze of the globalisation of innovation by identifying three main categories. These are: (a) the international exploitation of technology produced on a national basis; (b) the global generation of innovations; (c) the global technological collaborations.

The unit of analysis to which this taxonomy refers is either the innovation or the innovative research project. The intention is to list the ways economic institutions use to produce and exploit individual innovations and/or innovative projects. The three categories are complementary and not mutually exclusive, both at firm and country level. Firms, especially large ones, generate innovations in all the different ways described here. From a historical point of view, these categories emerged in three successive stages, even though the second and the third coupled rather than substituted the oldest one. The categories of this taxonomy are included in Table 1. [3]

The first category includes innovators' attempts to obtain economic advantages through the exploitation of their own technological competence in markets other than the internal one. We have preferred to label this category as 'international' rather than 'global' as the actors introducing the innovations preserve their national identity, even when the innovations are diffused and sold in multiple countries. In the majority of cases, the first market in which a specific innovation is exploited is the one it was

[3] This paper builds upon the taxonomy provided by Archibugi and Michie insofar as it constitutes a useful and practical framework of reference. Here, it has been extended in order to highlight the different, even though overlapping, effects, problems and policies linked to each of the three categories.

Table 1
A taxonomy of the globalisation of innovation

Categories	Actors	Forms
International exploitation of nationally produced innovations	Profit-seeking firms and individuals	Exports of innovative goods. Cession of licenses and patents. Foreign production of innovative goods internally generated.
Global generation of innovations	Multinational firms	R&D and innovative activities both in the home and the host countries. Acquisitions of existing R&D laboratories or green-field R&D investment in host countries.
Global techno-scientific collaborations	Universities and public research centres	Joint scientific projects. Scientific exchanges, sabbatical years. International flows of students.
	National and multinational firms	Joint-ventures for specific innovative projects. Productive agreements with exchange of technical information and/or equipment.

Source: adapted from Archibugi and Michie, 1995.

developed in: even firms which strongly tend towards foreign markets, use the internal markets as a 'laboratory' for their products in order to sample the reactions of consumers and the quality of the products. Some empirical evidence on the international exploitation of nationally produced innovations is provided in Table 2.

The most direct method for firms to appropriate the results of their innovatory activity in foreign markets is to export the products to which they are directly or indirectly incorporated. Another significant way of exploiting innovations in foreign markets is through foreign direct investment (FDI). The concession of both licences and patents, and the extension to foreign countries of patents released in the country where the innovation took place, are further types of international exploitation of national technological capacities. It should be remembered that this first category only includes the productive activity operated in host countries which does not

Table 2
Empirical evidence on the international exploitation of nationally produced innovations

Indicator	Source	Results	
		Stock	Trends
International trade	Guerrieri and Milana, 1995; OECD, 1996a; Guerrieri, 1997	High-tech absorbs 21.5% of world trade in manufacturing	Growth of high-tech from 9.5% in 1970 to 21.5% in 1995
Patents extended in foreign countries	Elaborations on OECD, 1996b	On average three extensions for each patent. Patents in fast growing and high-tech sectors are more likely to be extended abroad	Annual average growth of 13% in the period 1985–95
Technological balance of payments	OECD, 1996b	For the G6 countries in 1994 Payments were 11% of Business R&D Receipts were 16.4% of Business R&D	For the G6 countries in the period 1981–94 the average growth rates were 71% and 41.7% for Payments and Receipts, respectively

Table 3
Empirical evidence on the generation of innovations by MNEs

Indicator	Source	Results	
		Stock	Trends
Inward flows of R&D by MNEs	OECD, 1997	Foreign affiliates account for from 1% (Japan) to 46% (Australia) of R&D in manufacturing	Significant increase in Europe. Increase in USA. Moderate increase in Japan.
Outward flows of R&D in host countries by MNEs	USA Survey on R&D, National Science Foundation, 1996	7–10% of R&D of US firms is executed abroad (1980–93)	Small variations over time.
Patents generated in foreign subsidiaries of large firm	Patents granted in the USA by a sample of 569 large firms (Patel, 1995; Patel and Vega, 1997)	12.6% of patents is generated by foreign subsidiaries of large firms (1992–96)	Small but constant increase.
	Patents granted in the USA by a sample of 284 MNCs, Cantwell, 1995	15% of patents of US and European MNEs is generated in foreign subsidiaries (EU MNEs only: 27%) (1969–90)	Increase from 4% of 1920–24 to 19% of 1987–90.
Ownership of high-tech establishments operating in the USA	National Science Foundation, 1996	In 1995 10.9 of high-tech establishments owned by non-US companies	n.a.

entail the creation of additional local technological capacity: if this were to be the case, we would be moving from the first to the second category of this taxonomy.

The second category is the global generation of innovations, which includes innovations conceived on a global scale from the moment they are generated. Only innovations created by multinational enterprises (MNEs) are included in this category. With very few exceptions (such as Shell and Unilever), it is easy to identify the country of origin of such companies, so much so that to some they appear as

Table 4
Empirical evidence on global techno-scientific collaborations

Indicator	Source	Results	
		Stock	Flows
International inter-firm technical agreements	Hagedoorn, 1996; National Science Foundation, 1996	60% of inter-firm technical agreements are international.	Doubled over the 1980s. Slowdown in the 1990s.
Number of foreign students enrolled in higher education in developed countries	UNESCO, 1995	Share of foreign students from 1% to 17%	Increase in absolute terms, constant as a share of the total students.
Number of foreign post-graduate students in the USA	National Science Foundation, 1996	24% students enrolled in post-graduate courses are foreign (1994)	Increase of 4% in a decade.
Internationally co-authored scientific papers	National Science Foundation, 1996	10% of scientific articles (1988–93)	The number has nearly doubled from 1981–87 to 1988–93
		24% of the articles with more than one author (1988–93)	

Table 5
The regimes of the globalisation of innovation—interactions

Categories	Interactions		
	Firm/Firm	Government/Government	Government/Firm
International exploitation of nationally produced innovations	Strong competition to acquire market shares	Strong economic rivalry and protection of national production	Support to national champions and barriers to imports.
Global generation of innovations by MNEs	Competition for areas of economic influence. Rivalry to preserve the expertise and prevent imitation	Strong rivalry to attract and to acquire high-tech and R&D investments	Continuous negotiation for S&T investments and for public incentives to innovation.
Global techno-scientific collaborations	Collusive agreements between firms. Increased competition among inter-firms cartels	Bi-lateral and multi-lateral technical–industrial agreements. Control of monopolistic cartels. Bi-lateral alliances against other nations	Support to national firms to increase their international scope and the associated learning.

national enterprises with multinational operations (Hu, 1992).

The authentic global generation of innovations requires organisational and administrative skills that only firms with specific infrastructure and a certain minimum size can attain. Yet, the recent debate on where MNEs do actually locate their research and innovation activities has not achieved definite results. The empirical evidence on the share of innovation generated outside the home country of the MNE is still controversial as shown in Table 3 (Cantwell, 1995; Patel and Pavitt, 1991, 1994). However, although foreign subsidiaries of MNEs would appear to be primarily involved in the production of goods and services, data on patents registered in the US seem to indicate a slow but significant trend towards increasing shares of innovation generated outside the home country of the parent companies.

In recent times, a third type of globalisation of innovative activities has made a forceful entry on the scene. This, in some ways, is intermediate to the two preceding categories. We have witnessed an increasing number of national and international agreements between firms for the communal development of specific technological discoveries (Hagedoorn and Schakenraad, 1993). These forms of collaboration for technological advances have promoted a variety of mechanisms for the division of costs and the exploitation of results. In a way, the necessity to reduce innovation costs has created new industrial organisation forms and new ownership structures, which today are expanding beyond the simple technological sphere (Mytelka, 1991; Dodgson, 1993).

It was not the private sector that discovered this form of knowledge transmission. The academic world has always had a transnational range of action: knowledge is traditionally transmitted from one scholar to another and thus disseminated without always requiring pecuniary compensation. Table 4 reports some figures on the relevance of global techno-scientific collaborations. [4]

Each of the three categories of the globalisation of innovation identified here is also characterised by the existence of a specific international regime. Elaborating on what has been proposed by the literature on international regimes (cf., for example, Strange, 1988; Stopford and Strange, 1991), it is possible to identify for each of the three categories described, three main types of interaction: those between firms, those between governments and those between firms and governments. Table 5 summarises the competitive and cooperative conditions for each of the three dimensions of the globalisation of innovation, which will be considered separately in the following sections.

[4] For a wider and detailed discussion of quantitative aspects of the globalisation of innovation see the work of Archibugi and Iammarino, 1997.

3. The impact of the globalisation of innovation on the national economies

The answer to one of the questions previously raised, i.e., whether the globalisation processes are positive or negative, seems, in practice, to be conditional on a number of factors. The advantages, just as the costs, of the tendency towards an increase in the weight of global processes can be substantial and strictly depend upon the characteristics of the participating actors and of their interactions. It is necessary to bear in mind that the dimensions of globalisation summarised in the taxonomy have not affected the various areas of the world at the same time and with the same intensity. In fact, the expansion of global forces has remained limited to the more developed part of the world up to now, so much so as to have been defined a process of 'triadisation', in other words, of increasing polarisation of economic and innovative activities between the Triad economies—that is, Europe, North America and the Pacific Rim countries led by Japan (Chesnais, 1994). [5]

The most evident changes implied by the increasing globalisation are the tougher and increased competition and, simultaneously, the greater collaboration between actors, both across and within national boundaries. These changes, however, even though polarised in the most developed part of the world, might have an adverse impact on the economic and innovative performance of some countries and regions, leading to a higher risk of 'winners and losers'. Based on an analysis of the effects of the globalisation processes on national and local systems, it can be argued that the current tendencies do not seem to uniquely indicate a greater convergence towards higher levels of economic and technological activity within the group of most advanced countries, and even less so within the regions that constitute them. Considering each of the three aspects of globalisation separately, it is possible to outline the differences in the impact they may have on national economies and on the agents representing them, firms in particular. An attempt to summarise such differences is made in Table 6.

3.1. International exploitation of technology

The processes of market internationalisation and of the multinationalisation of productive activities are certainly the oldest ones in the globalisation phenomenon, and thus the ones that have been most studied. The expansion of market dimensions and their progressive integration have rendered the competition that firms in various countries and world regions must face ever more aggressive, both in domestic and in foreign markets.

The dynamic effects of trade have been increasingly dependent on technology and innovation. The proof of the importance of non-price factors in competitiveness (Thirlwall, 1979; Kaldor, 1981), identifiable principally in national technological capabilities, has anticipated the intense debate on technology as an 'endogenous' determinant of economic growth which has developed since the second half of the 1980s (for a survey see the work of Fagerberg, 1994). The dynamics of the increasing specialisation assume a crucial role in affecting countries' growth, as technological innovation does not occur evenly in the different sectors of the economy. Therefore, one pattern of specialisation is by no means as good as another: countries specialised in fast growing sectors (mainly high-tech) not only may experience faster growth, but they are likely to further reinforce their strength in the international division of labour, due to the cumulative character of technological progress (Lucas, 1988). On the other hand, it has been argued that market size and R&D are both positively correlated with specialisation in high tech sectors and competitiveness, via internal and external spillover effects (Grossman and Helpman, 1991). The exploitation of national technological competence might thus turn out to exacerbate the sectoral strengths and weaknesses of countries and to lead to technological

[5] As described by UNCTAD (1997), the activities of MNEs in less developed countries tend to be integrated with one of the Triad economies (between Africa and the EU, Latin America and North America, Asia and Japan and NIEs). The limited extent to which the globalisation of innovation has occurred in LDCs has been recently discussed by Callan et al. (1997). In this paper, however, the focus is on the advanced countries only.

Table 6
The globalisation of innovation—implications for the national economies

Categories	Implications for the national economy		
	Inward flows	Outward flows	Tendency towards convergence/divergence
International exploitation of nationally produced innovations	Low learning in consumption goods. Medium learning in capital goods and equipment.	Expansion of the market and of the areas of influence. Maintenance of national technological advantages.	Limited but significant economic convergence (GDP per capita). Technological divergence across countries.
Global generation of innovations by MNEs	Acquisition of technological and managerial capabilities. Increased dependence on the strategic choices of foreign firms.	Missing technological opportunities for the internal market. Strengthening of the competitive position of national firms. Tapping into the expertise of host locations.	Increasing regional/local divergence both in economic and innovation variables.
Global techno-scientific collaborations	Increase of techno-scientific flows. For developed countries, diffusion of their knowledge. For developing countries, acquisition of knowledge and learning opportunities.		Technological convergence across countries.

divergence (Cantwell, 1995; Vertova, 1998). [6] What are the possible effects of this increasing technological specialisation?

It is possible to maintain that among industrialised countries the opportunities to successfully exploit the national technological capacities increasingly depend on the relative size of the respective domestic markets. In fact, on one hand, large countries, such as the United States, have the advantage of a greater domestic profitability of innovation and of decidedly ampler spillover effects (Fagerberg, 1996). On the other hand, smaller countries, such as Switzerland, Holland and the Scandinavian countries, can exploit the greater concentration of their industries in a few strong sectors, and thus be in a position to act as global players, thanks also to the smaller fragmentation of their economic and political interests. Vice versa, medium sized economies, such as Italy, could have to face expensive restructuring processes of their productive apparatus. In fact, within the global competition framework, they would be unable to maintain a complete industrial matrix but also, given their size, they would not be content with 'niche' technology specialisations.

The growing competitive pressure implied by the globalisation process, however, is not limited to trade liberalisation between countries, since FDI flows have been increasingly featuring as complements to trade flows, actually overtaking them in importance as means of exploiting national competitive and technological capacities (Molero, 1997). The complementary relationship between FDI and trade tends to intensify their impact, possibly causing virtuous and vicious circles both in the investor's home country and in the host location (Cantwell, 1987). MNEs increasingly assimilate and integrate

[6] Several studies have addressed the issue of convergence from the viewpoint of efforts devoted by industrialised nations to technological expertise (see, among others, the works of Archibugi and Pianta, 1992, 1994; Patel and Pavitt, 1994).

with national and regional systems of innovation: their impact, however, depends crucially on the sectoral profile of the home and host economy. In trying to exploit their competitive advantage, firms relocating their production activity abroad may (but not necessarily) improve the local industrial capacity through more intense competition in the local market and the transfer of technology associated with the investment. The impact could be either 'driving' or 'enfeebling' with respect to the national technological and industrial base, depending on the pattern of sectoral specialisation and on the comparative 'strengths' of both investing and local firms (Iammarino and Michie, 1997). [7]

3.2. Global generation of innovation

Multinational enterprises are undoubtedly the most important actors in the worldwide generation of technology and innovation. The location of innovative activities of multinational enterprises in host countries is often linked to the location of their productive activity but, however strong the correspondence between productive activities and R&D activities may be, it will not be total. There are in fact different advantages and disadvantages linked to both the centralisation and the decentralisation of technological activities. The main advantages of centralisation—basically connected to economies of scale and scope in R&D, control on innovation and linkages with national business and non-business sectors—seem to be increasingly counterbalanced by those associated with decentralisation. From the investor's perspective, the latter can be summarised in terms of the linkages between innovatory activity and local production, markets, suppliers and clients, and the exploitation of technological fields of excellence in host countries (Pearce and Singh, 1992; Howells and Wood, 1993; Miller, 1994). All these factors acquire a greater or lesser importance depending on the country, on the type of firm, on the products and on the technologies involved.

The possible effects of the global generation of innovation on national economies are both direct and indirect (Dunning, 1992, 1993). The amount of innovation generated ex novo by foreign affiliates of MNEs—which includes also their demand and cost linkages with indigenous suppliers and customers and their impact on local market structure—minus the amount of 'diverted' innovation (i.e., that which would have been generated in the absence of MNEs), gives the net 'technology creation' effect. Therefore, MNEs' technological globalisation may enhance the nation's innovative capacity, as much as, in the wrong circumstances, it may weaken it. Cumulative causation mechanisms might thus occur, giving rise to vicious and virtuous circles which, again, strictly depend on the sectoral points of strength and weakness in both the home and the host economies. Moreover, it has been pointed out that the increasing number of networks established by MNEs, while boosting decentralisation through inter-border corporate integration of technological activities within the MNE, can further promote the advantages to agglomeration through inter-firm sectoral integration within national boundaries (Cantwell, 1994; Dunning and Narula, 1994; Cantwell and Iammarino, 1998). The 'competitive bidding' to attract high value added FDI and MNEs research activity is likely to become tougher, both between 'higher order' locations across developed economies, and between 'lower order' centres, the latter increasingly threatened by the emerging competitors from less advanced parts of the world. The risk of regional inequalities might thus increase also within countries, as 'centres of excellence' would be further encouraged, while backward regions would be further undermined by the strategies and policies of MNEs.

By taking into account differences in innovative capabilities across the EU regions—even more pronounced than at country level—it has been shown that they account for a good deal in explaining the diverging trend in economic growth observed since the later part of the 1980s (Fagerberg and Verspagen, 1996). The consequences of technological globalisation of multinational enterprises on indigenous innovative capacity might thus further exacerbate the

[7] Some examples of virtuous and vicious circles connected with inward and outward foreign direct investment are given by Cantwell (1987), Cantwell and Dunning (1991), Howells and Michie (1997).

disparities between the Northern and the Southern regions of the EU.

3.3. Global technological collaborations

As pointed out earlier, the business sector has been increasingly involved in global strategic technology alliances. The most frequently cited motivations are the so-called 'push' factors (Howells, 1997a), namely alliances established principally in order to cope with the complexity of the new, increasingly knowledge intensive, technological paradigms and to share the risks and costs associated with innovative activity (Katz and Ordover, 1990; Baumol, 1992). What marks these collaborations is that the firms involved maintain distinct ownership structures, while explicitly agreeing to exchange and/or generate, bilaterally or multilaterally, information and techno-scientific knowledge. [8] The 'pull' factors cover in fact the attractiveness of external sources of expertise over internal firm technological assets, and the desire to improve the scope of in-house scientific and technological competence.

The propensity of firms to collaborate, which emerged first on local rather than globalised markets (Becattini, 1987; Becattini and Rullani, 1993), surprised many of those who had studied the economics of the firm on traditional textbooks. In fact, firms are willing to share with other, often competing, firms a factor strategic to their own competitiveness such as technological competence, far more than it is generally assumed. It emerged quite early on that such collaborations were not only limited to the national level but that they went beyond national boundaries (Chesnais, 1988; Vaccà and Zanfei, 1989; Dunning and Gugler, 1992).

Collaborations are all the more advantageous among firms which do not compete in the same products and/or markets. Firms with similar technological knowledge can in practice have very different products, just as firms with similar products and technologies can be active on different markets due to either geographical location or the portion of demand they cater for. However, the notion of competition, although not directly implied by the third category of our taxonomy, shows a two-way link with that of collaboration. Cooperative agreements are nonetheless a source of comparative advantage, besides the traditional country/firm specific technological competence: they occur, in fact, to a much greater extent in industries in which competition is more pronounced, i.e., in the most recent technological sectors, as Biotechnology, Information Technology and New Materials (National Science Foundation, 1996). In fact, technological collaborations take place mainly in sectors characterised by oligopolistic and/or monopolistic competition, and they are based on high product differentiation and/or market diversification. Collaboration is therefore becoming a key determinant of competitiveness, which, in turn, requires more and more efforts to innovate.

Strategic agreements among firms do not wholly cover the phenomenon of global collaboration. As stated earlier, the academic world started this form of globalisation well before the business world. However, to the extent that the academic world has an influence on industry, its globalisation acts as a vehicle for the diffusion of knowledge and technological expertise.

It has been noted that the intensification of academic collaborations has been particularly boosted by regional economic integration processes. The highest increase in the shares of internationally coauthored articles during the eighties and the nineties has been registered by the EU countries, showing around 50% of coauthorships as international, mainly intra-area (National Science Foundation, 1996). This seems to support the view that knowledge processes crucially depend on cultural features whose similarities are more likely to be found within the same macro-region. [9]

[8] Mowery (1992) (p. 211) defines an international collaborative venture as ''interfirm collaboration in product development, manufacture, or marketing that spans national boundaries, is not based on arm's length market transactions and includes substantial and continual contributions by partners of capital, technology or other assets.''

[9] This emerges also by looking at other indicators, such as the international flows of researchers and foreign students enrolled in higher education. For instance, the huge increase of inflows recently experienced by Japan has mainly occurred from within the Asiatic region, as well as patterns of stricter collaborations are found among the members of the Asian and Pacific Economic Cooperation (APEC).

4. Implications for public policy

The considerations much above clearly show that globalisation processes in the field of technology and innovation constitute a major challenge for public policy. In particular governments, which exercise well-defined powers on a certain territory, find that their choices are strongly limited by processes they are not entirely in control of (Holland, 1987; Held, 1991).

The obstacles globalisation poses to government policies are all the more strong in the technological sphere, owing to the relative ease with which knowledge can be transferred across countries. Statements of the type ''Nasa research programmes favour Japanese firms'', or ''American universities train the managers of competing countries'' or even ''foreign firms are appropriating the national technological heritage,'' have become commonplace. [10] These preoccupations are linked to governmental action and they inevitably allude to certain political choices: in fact they prompt the following questions: is there any sense in financing great research programmes benefiting all world firms with national resources? Would limiting the access of foreign students be an effective way of preserving technological advantages? Should foreign firms be encouraged or discouraged from investing in R&D in the country?

Two different tendencies have emerged from the current debate on innovation policies. On one hand, there are those maintaining that government policies aimed at reinforcing a country's technological competence are irrelevant, given that resources employed would not necessarily lead to a national advantage (Ohmae, 1990). This 'technoliberal' vision is implicitly based on the assumption that knowledge and technology can be geographically transferred without much difficulty and that firms' innovating activity does not require the externalities produced by state action. On the other hand, there are those arguing that a larger public sector intervention is necessary in order to better equip every country to face the technological change currently occurring and the increased globalisation. This is the argument sustained by the approach based on national innovation systems (Lundvall, 1992; Nelson, 1993; Niosi and Bellon, 1994; Freeman, 1995; Archibugi and Michie, 1997b).

The specific argument we put forward here is that public policies play a different role in each of the three categories of the globalisation of innovation we previously outlined. As we emphasised in Section 3, each of the three categories has a very different impact on national economies. Governments will have different interests in each of the three globalisation types and this will lead them to opt for different strategies. In each case, either cooperation or competition will prevail. Is it possible to identify the advantages and drawbacks of each type from the interested country's viewpoint and, where possible, analyse the policies which could reinforce their economic and social utility? More specifically, which of these policies are to the advantage of some countries and to the detriment of others and which are advantageous all round? To what extent do the interests of a country coincide with those of its firms?

Let us start by assuming that it is, in fact, advantageous for a country to promote high technological intensity in its territory. This would allow for higher wages, for the creation of a demand for a more qualified labour force and, in the long run, for higher growth rates of value added and employment. In other words, technological activities generate a set of externalities benefiting the whole productive system. It is certainly unnecessary to convince governments about the importance of promoting and attracting technological activities on the territory they control. Public administrations have engaged in the attempt to make the greatest variety of arts and crafts flourish in their country for centuries. There has always been a current of thought attempting to promote the development and wealth of nations through interventions favouring science and technology, although it has been more active in political rather than in academic circles.

[10] These are recurrent echoes we find in the specialised press. Cf., for example, Foreign Passports, U.S. Doctorates, Issues in Science and Technology, Spring 1991, pp. 86–87; Foreign R&D in the United States, IEEE Spectrum, November 1994, pp. 26–30; High-tech jobs all over the map, Business Week, 19 December 1994, pp. 42–47.

Table 7 lists the main policy aims with respect to the three globalisation categories and mentions the available instruments, which will be discussed more extensively in the following sections. We emphasise that we have favoured reference to the larger category of public policy rather than the more limiting terms of innovation policy, industrial policy or even economic policy. In fact, it will become clear that in many cases the most appropriate policies are to be found in such diverse areas as those of training, education or public administration.

4.1. International exploitation of technology

This type of globalisation is the oldest among the types considered here and does not need a radical rethinking of the theories and policies applied to it. Furthermore, this form has the greatest quantitative relevance and presents the most sustained growth rates. It is thus logical that governments have focused their attention on it. It is also the type which directly evokes the rivalry among countries as every country has an interest in maximising the exploita-

Table 7
Public policies' targets and instruments for the globalisation of innovation

Categories	Targets		Instruments
International exploitation of national innovations	Inward flows	Achieving lower foreign dependency and filling technology gaps. Increasing learning.	Incentives to national infant industries. Promoting collaborations between national firms and leading firms in the field. Incentives to selected FDI in the country.
		Obtaining competitive supply prices.	Negotiations on imports with the firms of other countries.
	Outward flows	Supporting national firms to appropriate their innovations.	Export incentives for high-tech industries. Property rights negotiations.
		Preserving and developing competitive advantages in high-tech industries.	Public support to basic research and technology dissemination. Ensuring fair competition. Reinvesting profits in new innovative projects of international scope.
Global generation of innovations by MNEs	Inward flows	Enhancing national technological capabilities.	Providing real incentives to the location of new innovative activities with foreign capital. Upgrading S&T infrastructures and institutions.
		Keeping control on foreign capital.	Monitoring the technological strategies and location choices of MNEs.
	Outward flows	Strengthening the competitive position of national firms.	Assessment of the need of home-based MNEs to invest abroad in R&D and innovative activities.
Global techno-scientific collaborations	Scientific	Upgrading the scientific competence of the nation.	Scientific exchange programmes. Incentives to international scientific projects. Participation to international S&T organizations.
	Techno-industrial	Allowing the country to become a junction of technical and industrial information. Applying knowledge to production.	Developing infrastructures for techno-collaborations (scientific parks, consortia, etc.). Promoting University/industry linkages Participation to international organizations for technical and industrial collaborations.

tion of its own competence and symmetrically minimising the costs associated with the acquisition of others' competence.

It is advantageous for a country to sell its own products in foreign markets and, as noted above, the advantage becomes even greater if competitiveness is based on sophisticated technological knowledge rather than price. In fact, the former allows the application of profit margins which are difficult to sustain in areas in which technological barriers to entry are very low. Thus, the preoccupation of political advisors with providing support for industries exporting goods of high technological opportunity seems well-founded (Pianta, 1988; Tyson, 1992; Scherer, 1992). It is certainly not by chance that governments provide support for the competitiveness of national firms by favouring their innovation programmes, so much so that technological policies are increasingly being merged with commercial policies (Caldwell Harris and Moore, 1992; Mowery, 1995).

There are some general policies which must be implemented to enable national firms to maximise the exploitation of their technological competence in foreign markets too. Apart from the availability of informational networks such as the BBC or CNN, incentives to export, real services supplied abroad and decent diplomatic offices, all favour the access of a country's firms to foreign markets. These policies do not favour specific sectors only and can be applied as much to shoes as they can to semiconductors. It should be reminded, in fact, that innovation plays a crucial role in all industries, and not only in those commonly defined as high-tech. However, many countries have started becoming more selective and are gearing their energy and resources towards the support of the most innovative goods and services on foreign markets. Besides, as pointed out in Section 3, the success of national firms in competing in global markets will depend increasingly on policies aimed at monitoring and regulating inflows and outflows of embodied and disembodied technology. For example, the need for governments to have some degree of control over the quality of inward and outward FDI is becoming much more pressing in a context of increased globalisation. The proactive strategy implemented by Asian economies, which applied the technology imported through inward FDI in production to empower the domestic industrial and innovative base, is often reported as an example of the national capacity to build a 'sustainable competitive advantage' (Sugden and Thomas, 1994).

Firms have an interest in preserving their technological advantage and in preventing competitors from imitating successful innovations. They implement various strategies aiming to reveal their competence as little as possible, as this allows them to obtain a revenue now and to mortgage one for the future. Governments concur to help national firms preserve and extend their technological advantages. A frequently quoted case is the English Parliament's prohibition of the export of machinery and even of the emigration of artisans up to 1842 in order to prevent Continental Europe from acquiring the technological competence which made English firms the most competitive in the world (Landes, 1969; Bruland, 1989). Such policies, although better disguised, are implemented in many countries to this day. Symmetrically, it is in the importing country's interest to attempt to facilitate the assimilation of knowledge thus enabling the emancipation from the dependence on suppliers. This suggests that, for example, the provision of support for firms which are active in certain industries or the provision of structures, such as the creation of advanced University programmes, allow the country to acquire the knowledge necessary for production. It is certainly significant that the policies proposed by Fredrich List (1841) to enable Germany to compete on equal grounds with Great Britain in the mid-19th century, are recommended today for developing countries (Freeman, 1995; Bell and Pavitt, 1997).

Contrary to what was happening at the beginning of the 19th century and in the first post-war period, the modern world is not characterised by a solid and generalised technological supremacy of a single country. During the pax Britannica and the pax Americana, both England and the United States had a political, economic and technological hegemony. In the modern world, the division of labour is not such that a single country has a marked advantage in all the high-tech industries (Nelson and Wright, 1992). This constrains all industrialised countries, including the larger ones, to select the technological areas in which they intend obtaining a share in the global markets and those in which they intend relying on imports. This observation is corroborated by

three facts: (1) technological competence is very different among developed countries. This is reflected both in the sectoral distribution of their innovations (Archibugi and Pianta, 1992) and in their international commercial specialisation profiles (Amendola et al., 1997); (2) as stated earlier, the differences in each country's technological competence have increased (Archibugi and Pianta, 1992, 1994); (3) the place occupied by a country in technological and commercial specialisation tends to remain constant over time (Cantwell, 1989; Amendola et al., 1997).

Hence, one of the factors allowing a country successfully to exploit its technological competence in foreign markets is the careful selection of the sectors on which it chooses to focus, given its existing competence. The latter, however, reflects the cumulative pattern of national production and skills acquired over time, which itself limits the scope of search for new opportunities. In a world in which the international exploitation of technology is growing, clearly visible weaknesses in certain technological sectors do not constitute a problem for a country, as long as they are offset by equally visible strengths. Japan, for example, is not present in certain high-tech sectors (it had to abandon aeronautics in the post war period and it never entered the nuclear sector) and has concentrated instead on other sectors such as motor vehicles and electronics. However, Japan's negotiating position is strong even in the sectors in which it is absent as it is 'covered' by the advantages of its leading industries. Thus, it does not appear to be vulnerable to the blackmail of competing countries. Therefore, the problem is not so much to know how to do everything as it is to have enough merchandise to exchange in order to be able to negotiate from an equal standing. Furthermore, in a multipolar world, the greatest risk faced by a country is its inability to find markets for internally generated products rather than to see the imports of certain technologically strategic goods refused.

However, the absence of national 'strongholds' in at least some industries with higher technological opportunities can weaken the competitive position of a country and notably reduce wage levels, employment rates, professional qualifications, and total economic welfare (Freeman and Soete, 1990, 1994). Are there ways to identify the most convenient and congenial technological and commercial specialisation for a country? Many analyses have focused on international trade classified according to the technological intensity of products, [11] showing, as we already noted, that production and international trade shares of high-tech products are growing. This indicates that a country specialised in such sectors will be operating in expanding markets. Other analyses have explicitly considered the sectoral growth rates of innovation generation (cf. the works based on patents by Meliciani and Simonetti, 1996; Breschi and Mancusi, 1997). They show that the rapidly growing sectors and the high-tech ones coincide. They have also allowed the identification of the high growth sectors with the lowest technological barriers to entry. Various countries have promoted more complex and accurate studies of technological forecasting, [12] and in many cases these are explicitly connected to the industrial policy strategies to be implemented in order to reinforce the competitive position of national firms on foreign markets.

Yet, it is certainly neither easy, nor often possible, to 'move' a country's specialisation towards different sectors, especially if they are the ones with more sophisticated technological competence. Success in fields requiring a high technological competence is risky in the first place, because technological and economic uncertainty increases with the complexity of the required competence. The Italian case confirms how many 'false starts' there can be in sectors deemed strategic (steel, petrochemicals, aeronautics). A large amount of resources was invested in such sectors without the Italian industry ever managing to take off beyond the mere necessity to satisfy, and even then only partially, the internal market.

Indeed, there are various actions which may help strengthen the competitiveness of national firms in high-tech industries, such as: public support of basic research and research infrastructure, which actually

[11] Different methodologies to identify the sectors with high technological opportunity have been applied by Guerrieri and Milana (1995), Grupp (1995) and Amendola and Perrucci (1995).

[12] For a review of the studies made and of the methods used, cf. Martin (1995).

affects all sectors of the economy; tougher competition policies, which stimulate innovativeness by increasing rivalry in the domestic market, especially in the most 'sensitive' sectors (such as strategic or emerging high-tech sectors); reinforcement of technological dissemination and participation mechanisms, particularly as far as small and medium firms are concerned; support both to pre-competitive R&D in new strategic sectors and to market-oriented R&D in already existing technological advantages. An international system marked by increasing of exchange and in which the competition for the exploitation of innovations is growing does not require technological autarchy, but directs countries towards the research for specialisation in fields with high innovation intensity. In other words, it requires them to have desirable goods in order to negotiate from an equal standing.

4.2. Global generation of technology

We have already discussed the importance of multinationals in generating innovations. The size of these enterprises influences countries' actions in more than one way, to the extent that the term meso-economy was coined (Holland, 1987) to describe the range of action of their operations and the constraints they impose on national macroeconomic policies.

As regards this form of globalisation, governments have to deal, in practice, with ''national firms with multinational operations'' (Hu, 1992), as the title of a seminal study shows. In this case, what are the interests a government must pursue? On one hand, it is presented with national enterprises which were founded, grew and became competitive thanks to the resources of the national economy and could now need to decentralise their technological activities to third countries in order to expand their business scope and maintain their competitiveness. However, as we have seen, from the point of view of the country, this relocation might even be damaging, to the extent that the internal market looses technological opportunities. On the other hand, the same national government finds foreign firms (and as such with preferential ties with foreign governments) which intend to reinforce their own position through investments in the country. This implies the influx of new capital and technology for the host country and often the creation of new qualified employment, but could also imply the weakening of national firms. Governments have to accept that the long run strategic intentions of the foreign firms are often uncertain.

The difficulty for a government to identify the real interests of its own country is de facto confirmed by the existence of different positions both in theory and in practice. Some governments, inspired maybe by the sceptics of globalisation (Patel and Pavitt, 1991; Hu, 1992) exclude the subsidiaries of multinationals from eligibility to R&D subsidies. Other governments, converted to the idea that property is irrelevant, have emplaced specific incentives in order to attract foreign capital. One of the most explicit supporters of this vision, the former US labour secretary Robert Reich [Reich (1991), p. 301], has sustained that ''rather than increase the profitability of corporations flying its flag, or enlarge the worldwide holdings of its citizens, a nation's economic role is to improve its own citizens' standard of living by enhancing the value of what they contribute to the world economy. The concern over national 'competitiveness' is often misplaced. It is not what we own that counts, it is what we do.'' Yet skills and capabilities associated with foreign investments are arguably of growing importance, while ownership has become less relevant; learning curve advantages are mainly people- and institution-embodied and local firms may benefit from global corporations investing in innovation and local human capital (Sharp and Pavitt, 1993).

Public policies should attempt to distinguish between investments directed towards the creation of technological capacity in a country from those of simple acquisition. Although it could be thought that the creation of additional technological competence is always advantageous for a country, a government should have instruments to defend national firms exposed to predatory acquisitions by foreign capital (Mariotti, 1993). In many cases, multinationals have an interest in acquiring foreign competitors and then merge, reduce or even liquidate the subsidiary's R&D laboratories. Although such strategies may be justified from the firm's point of view, they impoverish the technological basis of a country. It is for such cases that an industrial policy aimed at protecting the

'family jewels'—which are the most technologically active firms and, precisely for this reason, the ones most exposed to the appetites of their foreign competitors—is necessary.

Beyond individual cases, governments should observe the aggregate and, even more, the sectoral flows of investments with high technological content entering and exiting the country, in order to assess the extent to which their country offers the appropriate environment for the development of innovative projects. If the inflows are structurally weak, the reasons for this occurrence should be identified. These may include an insufficient infrastructure level, excessive institutional rigidities, the absence of adequate interlocutors in the Universities and in the public research centres. Each of these factors can be dealt with through appropriate public policies. Indeed, as reported in Table 7, all the above factors apply both to inward and outward flows. The quality of local science and technology infrastructure, as well as that of institutional relations, also help attract and expand new technological activities from abroad. It is thus suggested that the aim of public policy is not to maximise the values of nationally-owned assets, but rather to stimulate high value added activities of local contexts and communities.

Moreover, governments should not just look at the ways through which national competitiveness can be enhanced vis à vis foreign rivals. It is becoming increasingly important also to consider more carefully the distribution of the benefits and costs implied by the globalisation within the national borders, and the potential gap between private and social returns to innovative activity. As we have suggested in Section 3, the global generation of innovation by MNEs might give rise to more dramatic imbalances, as they occur in national environments which are supposed to be—at least in principle—more economically and socially homogeneous than the international one. The link between 'global' and 'local' needs to be shaped by the government action. As Hirst and Thompson (1996) (p. 184) have properly remarked, ''the nation state is central to this process of 'suturing': the policies and practices of states in distributing power upwards to the international level and downwards to sub-national agencies are the sutures that will hold the system of governance together. Without such explicit policies to close gaps in governance and elaborate a division of labour in regulation, vital capacities will be lost.''

4.3. Global technological collaborations

As claimed above, unlike the two previous types of globalisation this type does not necessarily impose competition among countries. On the contrary, it is mainly characterised by the existence of a positive sum game in which participant economic agents can all obtain advantages. This, of course, does not mean that the advantages received by participants are identical; it is probable that in each cooperative agreement there are firms which get more advantages than others. These, however, are considerations that go beyond the functions of public administration. What governments should be concerned about instead is to ensure an adequate level of competition in the domestic market. In fact, the degree to which such agreements on technological cooperation are collusive and thus detrimental to internal competition and consumers' interests or, on the contrary, offer generalised advantages because they act as a tool for the diffusion of knowledge which would otherwise remain localised, is still controversial and needs more careful evaluation.

The interests of a nation which a government is called to foster consist of aiding its firms to participate in this form of international integration and putting them in the position to enter the virtuous circle which from collaboration leads to learning and from learning to innovation. This can be obtained either through inter-governmental agreements, or through international organisations. Watkins (1991) has argued that national governments are in a unique position to help firms to overcome market failures (i.e., negotiations and technology communications difficulties posed by complex, rapidly advancing technologies). However, market failure is not alone sufficient to guide policy actions. By providing a broader model of R&D cooperation (what Watkins calls the 'umbrella-consortia paradigm' at the European Union level) than merely financing R&D, governments can play a major role in fostering technological innovation and diffusion. In Europe, some such schemes were implemented via the Eureka project and, in more stable form, through the various

Framework-programmes promoted by the European Commission. What rendered these schemes particularly effective, was that they brought about a competition (through a public competition and an evaluation based on merit of the applications presented for funding) of a variety of projects involving partners from more than one country. This should allow the selection of the projects of the greatest technical and scientific interest among the cooperation proposals. The prevalent 'pull' factor is thus represented by policies and incentives to join collaborative research and technical projects implemented by the EU institutions. The participation rate to such projects varies considerably across countries and some evidence has been provided about trends towards geographical clusters of collaborations (Lichtenberg, 1994).

Some authors, however, have expressed concerns about the efficiency and efficacy of European technology policies for international collaboration within Europe (Soete, 1991). In fact, on one hand, collaborations requirement may not be the best means of diffusing information among firms, particularly among SMEs, which are reluctant to participate in consortia aimed at basic research. On the other hand, the complementarity and coherence between programmes implemented by the various levels of government within the EU should not be taken for granted, as well as the consequences of EU cost subsidies on firms' incentives to share know-how (Soete, 1991; Perez Castrillo and Sandonis, 1997). Therefore, it seems central to reinforce the transparency of the modalities, the coordination between EU-wide and national programmes and the participation mechanisms, encouraging the access of small and medium enterprises and giving everyone the same amount of information on the procedures to join such international collaborative schemes.

Moreover, beyond the institutional agreements—whether bilateral or multilateral—public administration has the tasks of creating an infrastructure in its own territory and sustaining domestic technological collaboration and education, which could render the country attractive for cooperation. It is clear that the greater its technical and scientific potential the more a country will be an attractive partner. Even developing countries can be equally interesting partners if they possess adequate infrastructure, including communication networks, qualified research personnel, a widespread knowledge of the international languages, etc. Furthermore, firms from advanced countries will have an incentive to collaborate in countries with expanding markets. Yet providing a strong infrastructure is certainly a prerequisite for international collaboration, but it is not sufficient as long as technological performances can also be explained in terms of 'institutional failure' (Abramovitz, 1986). As noted earlier, the modernisation of the role of institutions in charge of the diffusion of science and technology is essential, as the lack of appropriate relations between education systems and industry or financial systems and business sector can provide a serious drawback to the development of scientific and technical collaborations.

In the long run, it seems that this is the type of globalisation which most reinforces a country's scientific and technological potential and, therefore, its competitive performance. In fact, it allows a country to become an information crossroads and thus to acquire expertise in a wide range of technologies. Spillovers and knowledge transfer through this form of technological globalisation can indeed be substantially wide, especially whether collaboration involves the partnership of different actors—namely governments, institutions and the business sector—indirectly affecting competitive performances, too. Thus, it appears reasonable that public policy should provide the greatest possible incentives for the development of international cooperation.

5. Conclusions

In this paper, we have attempted to specify what the globalisation of innovation consists of, who are the participating subjects and, on the basis of the possible impact globalisation might have on national economies, to identify the role of public policy. We developed a taxonomy which broke down the phenomenon into three categories: exploitation, generation and collaboration. It emerges that the most diffuse type of globalisation is the international exploitation of innovation developed on a national basis. It is, in practice, comprehensible that this type is quantitatively the most prominent given that it is also the oldest one. However, the most significant

fact is that this type has a higher growth rate than the other two, to this day.

The globalisation of innovation by multinational enterprises is achieving a certain quantitative relevance, although much less significant than often stated. The effects of such trend towards increased global generation of innovation on national and local systems are, moreover, rather uncertain. Both virtuous and vicious mechanisms of cumulative causation may occur, spurring or weakening national and local innovative capacity and affecting economic and technological convergence across and within national boundaries.

Finally, during the last 20 years, a third type of globalisation has come into being, represented by the cooperative strategic arrangements among firms for innovative projects. As in the case of the first, this type of globalisation is more prominent in sectors with higher technological opportunity. Although it is difficult to quantify the economic value to be associated to this type, it has shown a sustained growth rate.

We have also suggested that a single strategy to deal with the three different types of globalisation does not exist, neither from a firm's nor from a government's point of view. These are three different problems and, although they partly overlap, they should be treated separately.

It is, however, important to emphasise that none of the three categories in this taxonomy renders public policy obsolete. On the contrary, public policies on a far wider range than those currently practiced in the majority of countries are necessary, so that nations should best exploit the opportunities associated with the globalisation of innovation and offset the risk of winners and losers. The benefits from globalisation, in fact, will not be reaped without any cost, nor will the challenges be met without adjustment. The globalisation process thus offers many opportunities to strengthen policy effectiveness, both by enabling governments' structure to function in an interdependent world and by examining more carefully the impact on national economies. Even though we know the contribution of technology and innovation to the economic performance, further progress is still needed in measuring the extent and the distribution of these contributions in an increasingly globalised world. The globalisation of innovation thus requires an expansion of the public policy portfolio. That governments should also know how to plan and implement them is, obviously, a different story.

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