The Globalisation of Technology and its Implications for Developing Countries. Windows of Opportunity or Further Burden?

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ABSTRACT

Technologies are playing a crucial role in allowing the globalisation of economic and social activities. The ways in which new technologies penetrate individual nations is heavily affecting their actual and potential economic development. On the basis of a categorisation of the different forms of the globalisation of technology, this paper explores the impact on developing countries.
It is argued that international trade of high tech products and of intellectual property rights does not ensure the economic and technological upgrading and development of emerging countries, as it makes it different to increase endogenous learning. Since this is still the most relevant form of international transmission of know-how, developing economies should implement policies which will allow them not only to import high technology products and processes, but also to absorb, imitate and develop them.
Another relevant vehicle of transmission of know-how is related to Foreign Direct Investment (FDI). The investments of transnational corporations (TNCs) offer important opportunities to developing countries, but they might also be an obstacle to the making of an endogenous innovation system if they are not coupled with a strategy to improve absorptive capacity.
A third form of transmission of know-how is via international co-operation programmes. Both academic institutions and business companies are involved in these trans-border collaborations. It is argued that they can be very beneficial to develop endogenous scientific and technological capabilities in developing countries.

OUTLINE:

1. Introduction

The international transmission of know-how, knowledge and technological expertise is growing and it is increasingly important in the world economy. The weight of science-based commodities is constantly increasing in world trade (Guerrieri, 1999), foreign direct investment (FDI) by transnational corporations (TNCs) is an important vehicle for the transmission of innovation across the world (Cantwell, 1989), trans-border scientific and technological co-operation is absorbing more energies and resources of governments and firms (Dogdson, 1993). But how important is it for developing countries (LDCs)? Are they participating in these flows or are they rather staying aside and observing them? And, more importantly, how are their technological capabilities affected by the fact that the flows of knowledge have considerably increased?

The aim of the paper is to:

- Define the globalisation of technology with the use of a new categorisation
- Measure the degree of developing countries' participation in the globalisation of technology
- Discuss the relevance and impact of the globalisation of technology on developing countries, and its implication for their development strategies and policies.

The specific form and extent of technology globalisation for developing countries bears important consequences for their government action, and implies an especially active attitude towards innovation policies. It will in fact be argued that the globalisation of technology offers new opportunities for development, but that they are by no means available without deliberate effort to absorb innovation through endogenous learning.

The next section reassess the concept of technology which informs this paper since we believe that this is particularly important to design appropriate strategies and policies. Section three reports a taxonomy on the different forms that the globalisation of technology can take; this will help us in order to measure the significance of globalisation and to assess the various strategies undertaken by governments and firms. Section 4 documents to what extent developing countries are taking part in the globalisation of technology; although the evidence available is still unsatisfactory, it clearly emerges that the bulk of technological activities are both produced and exchanged among the most advanced countries. The last section discusses the advantages and the disadvantages associated to the strategies which developing countries can undertake in order to bridge their technology gap and to integrate themselves into the club of the more innovative and dynamic nations.

2. What is technology?

Technology has often been studied by economists with the tools of analysis of a competitive market. Thus, if technology may be studied like any other commodity, and if markets were freely working and perfect competition prevailed, then no problem of technology transfer would pose. Technology (from whatever source) would be easily transferred and utilised. The efficiency of its use would only be a matter of ensuring the conditions for efficient resource allocation in the context of exogenously determined technological alternatives. Technology policy would only consist of government sponsorship of institutes that collect, process, and disseminate technical information, justified as a provision of public goods. This conception descends from two assumptions : (i) technology consists simply of a set of techniques wholly described by their 'blueprint' ; (ii) all techniques are created in the developed countries, from which they flow at no or low costs to developing countries (for a recent reaffirmation of this old belief, see Mankiw, 1995).

However, several authors recognised, already a few decades ago, the special features of technology and technological change, leading to a perception of technology in more complex terms. Thus, first of all, no existing technique is completely expressed by the sum and combination of their material inputs and the codified information about it. In fact, much of the knowledge about how to perform elementary processes and about how to combine them efficiently is tacit, not feasibly embodied, nor codifiable or readily transferable, and 'a firm will not be able to know with certainty all the things it can do, and certainly will not be able to articulate explicitly how it does what it does.' (Nelson, 1987:84)

This means that technology is not simply a set of blueprints, or of instructions, that if followed exactly will always produce the same outcome. Although two producers in the same circumstances may use identical material inputs with equal information available, they may nonetheless employ two really distinct techniques due to their different understanding of the tacit elements. Thus, techniques are sensitive to specific physical as well social circumstances (Evenson and Westphal, 1995:2212)

Moreover, technology is not instantaneously and costlessly accessible to any firm: a firm *does not simply select the preferred option* from the freely available international technology shelf, as there may obstacles and difficulties in obtaining the desired technology. Simply choosing and acquiring a technique does not imply operating it efficiently ('at best practice'). Individual firms do not have a complete knowledge of all the possible technological alternatives, their implications, and the skill and information they require. The entire production curve, illustrating an infinite number of alternatives, is not known to the individual firm, as neo-classical theory assumes. To the extent technologies are tacit, firm production sets are fuzzy around the edges (Nelson, 1987:84).

Understanding technology in these more complex and realistic terms implies that tangible and intangible investments in technology are required whenever technology is newly applied. This applies to domestic as well as foreign imported technologies. Each firm has to exert considerable absorptive efforts to learn the tacit elements of technology, and gain adequate mastery. This is at the opposite extreme from the neo-classical premise that technology, as well as productive inputs and outputs, is perfectly known. This knowledge is not instantaneously and costlessly available to all firms, and technology transfer poses substantial problems of adaptation and absorption that are related to investments in technological capability i.e. the complex array of skills, technological knowledge, organisational structures, required to operate a technology efficiently and accomplish any process of technological change.[1] This dynamic technological effort implies a process of learning that is qualitatively different from the traditional 'learning by doing', as it involves an active attitude. Learning may be pursued in a variety of ways (Bell, 1984), and the passive 'learning from operating' is only one possibility.

A powerful way of learning is by training within producing firms. This has the disadvantage that training will probably stay at a level below what would be socially optimal, because of the well-known problem of incomplete appropriability of its results, but in-firm training will be more appropriate as the firm will provide exactly the kind and quantity of training necessary for the absorption and advancement of technology (Enos, 1991:80). Furthermore, learning itself has to be learnt, as it is a highly specialised process, that involves the organisation of the accumulation of technical knowledge (Stiglitz, 1987).

In addition, even if the need for learning efforts is acknowledged, investing in learning does not ensure success. This is due to the stochastic nature of the learning process, that is influenced by the external environment and by firm's actions, and results from dependence on historical circumstances, entrepreneurial skills and luck. Therefore, different firms may reach persistently different levels of efficiency and dynamism, also in competitive markets (Nelson, 1981, Dosi, 1988).

Within this broader context, technology transfer becomes an important issue that has to be assessed jointly with a country' capability to make use of technology, absorb it and adapt it to local conditions. In other words, technology transfer links foreign technology access and acquisition to its efficient use for economic development, and to the catching up of the relatively technologically backward countries (Evenson and Westphal, 1995).

Thus, the access to and acquisition of foreign advanced technology, by itself is not sufficient to ensure local technological and industrial development. Several other elements are needed. An additional central component of a country's industrial development policy strategy is technological effort oriented to the absorption, adaptation, mastery and improvement of technology. This itself implies a continuous process of technological change (Katz, 1987, Lall, 1992a).

Once this conception of technology is accepted, it is much easier to understand that the globalisation processes will have a very different impact in technology and that there is no reason to assume that globalisation will provide benefits to all regions and agents. The next section presents a taxonomy of the globalisation of technology which may help to identify the various forms to exploit and acquire know-how.

2. A New Taxonomy of the Globalisation of Technology

In the last few years, too many heterogeneous phenomena have been lumped together under the label the globalisation of technology, and the concept has thus lost much of its significance. We thus attempted (Archibugi and Michie, 1995; 1997) to find our way in the labyrinth of the globalisation of technology by identifying three main categories:

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[1] References on the theory of Technological Capabilities include Bell and Pavitt, 1992, Enos, 1991, Fransman and King, 1984, Katz, 1987, Lall, 1990, 1992, Pack and Westphal, 1986.

a) the international exploitation of nationally-produced technology;
b) the global generation of innovation;
c) global technological collaborations.

The aim of this taxonomy is to classify individual innovations according to the ways in which they are exploited and diffused internationally. Both at single enterprise and national levels, the categories are complementary, not alternative. Enterprises, especially large ones, generate innovation following all the three procedures described. From a historical point of view, these categories emerged in three different stages, even though the second and the third added to, rather than substituted the oldest one. The categories of this taxonomy and the main forms through which the three processes manifest themselves are shown in Table 1 (for their empirical importance, see Archibugi and Iammarino, 1998), while Table 3 reports the implications of the globalisation of technology for national economies.

The international exploitation of technology produced on a national basis

The first category includes the attempts of innovators to obtain economic advantages by exploiting their technological competencies in markets other than the domestic one. We have preferred to label this category 'international' as opposed to 'global', since the players that introduce innovations preserve their own national identity, even when such innovations are diffused and marketed in more than one country. Firms may opt to a variety of strategies in order to obtain economic returns from their innovations in foreign markets.

The oldest form which firms have used to profit from their innovations in overseas markets is to trade products with a technology-based competitive advantage. New products and processes have often been exempted from the trade restrictions of traditional merchandise since the importing countries were not able to generate competitive domestic alternatives. It is however well known that to export technology-intensive products provide an advantage to the exporting countries and that the importing countries increase their know-how dependence unless they are able to bridge the gap in competencies.

Exports are not the only form according to which firms can exploit their technological advantage in overseas markets. Another way is to transfer the know-how to firms based in overseas markets, for example by selling licences and patents. This form of technology transfer would however require that the firms of the host country have already the capabilities to exploit new ideas and devices into production. It is likely that in the long run the importing country will be able to move up-stream in the value-added chain and to become able to generate autonomously at least part of the know-how connected to production.

There is a third important form of exploiting in overseas markets the innovation generated at home, i.e. to install through foreign direct investment productive facilities in host countries in order to produce *in loco* new products and processes. Production plants in host countries which do not contribute significantly to the generation of the know-how, but simply that they put into production already designed artefacts, are considered here. If, on the contrary, there is a significant participation of the plants in host countries to the design of the products, we move from the first to the second category of this taxonomy.

The global generation of innovations

The second category is represented by the global generation of innovations. It includes innovations generated by single proprietors on a global scale. Only innovations produced by multinational enterprises fit into this category. 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 TNCs actually locate their research and innovation activities has not achieved definite results. The global generation of innovations may be obtained by locating overseas R&D laboratories and innovation centres. This can be achieved both through the acquisition of existing laboratories or by green-field investment in host countries.
Bartlett and Ghoshal (1990) have singled out three main strategies of TNCs:
Centre-for-global. This is the traditional 'octopus' view of the TNC: a single 'brain' located within the company headquarters concentrates the strategic resources: top management, planning, and the technological expertise. The 'brain' distributes impulses to the 'tentacles' (that is, the subsidiaries) scattered across host countries. Even when some overseas R&D is undertaken, this is basically concerned with adapting products to the needs of the local users.
Local-for-local. Each subsidiary of the firm develops its own technological know-how to serve local needs. The interactions among subsidiaries are, at least from the viewpoint of developing technological innovations, rather weak. On the contrary, subsidiaries are integrated into the local fabric. This may occur with conglomerate firms, but also in the case of TNCs which follow a strategy of technological diversification through tapping into the competence of indigenous firms.
Local-for-global. This is the case of TNCs which, rather than concentrating their technological activities in the home country, distribute R&D and expertise in a variety of host locations. This allows the company to develop each part of the innovative process in the most suitable environment: semiconductors in Silicon valley, automobile components in Turin, software in India. The effectiveness of such a strategy relies on the intensity of intra-firm information flows.

The global technological collaborations

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. Technological collaborations occur when two different firms decide to establish joint-ventures with the aim of developing technical knowledge and/or products. Three conditions need to be respected: i) the joint-venture should be something more than an occasional and informal collaboration: ii) firms preserve their ownership; iii) the bulk of the collaboration is related to sharing know-how and/or the generation of new products and processes (Mowery, 1992).
We have witnessed and increasing number of agreements between firms for the communal development of specific technological discoveries (Hagedoorn and Schakenraad, 1993). Such collaborations often take place among firms of the same country, but in many cases they involve firms located in two or more different countries, thus emerging as authentically global.
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 need to reduce the costs of innovation – and to cope with its increasing complexity – 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 radius of action: knowledge is traditionally transmitted from one scholar to another and thus disseminated without always requiring pecuniary compensation. Since the involvement of the academic community into the business world is more and more demanded, the forms of diffusion of know-how within Universities and other public research centres have become of increasing importance for industrial development.

3. Evidence on developing countries' involvement in the globalisation of technology

It is rather clear that the different forms of the globalisation of technology singled out in the section above have different implications for national economies. Each of them will have a different impact on learning and, eventually, on local economic development. This section, on the basis of the available evidence, document the involvement of LDCs in each of the three categories discussed above.
First of all, it is important to stress that the generation of new technologies and innovations in LDCs is still negligible. Indicators of the production of knowledge show that the major innovative activities are heavily concentrated in the Triad countries. This especially apply for the more formalised forms of knowledge creation. Resources invested in R&D are for example heavily concentrated in advanced countries, which alone perform more than 90% of the world expenditure. Equally heavily concentrated in advanced countries are patents. The discussion above on the nature of technology may suggest that a national capacity can be created even without a massive R&D effort, but simply concentrating on the diffusion of technology created in other countries. Other indicators of the available skills, such as the education level, show that the gap between developed and developing countries is somehow smaller. But, above all, they show the existence of great differences within developing countries. It is certainly significant that countries that have a better performance in education indicators are the same that have a significant and growing share of R&D and patents. For example, Taiwan and South Korea inventors alone have registered more patents in the United States than all other developing countries of the world together.

Evidence on the international exploitation of technology produced on a national basis

Concerning trade in technology-intensive products, developing countries continue to be mainly 'invaded' by developed countries. However, this does not appear to be the only possible outcome, since the group of Asian NICs has managed to conquer successfully significant shares of the world markets. It is certainly significant that Asian NICs concentrate as much as 11% of world trade in high tech, while Latin American NICs, which were not disadvantaged at the beginning of the 1970s, have not upgraded significantly their positions.
It is certainly not surprising that the same degree of involvement applies when we consider the trade of disembodied knowledge measured by the technological balance of payments.

Evidence on the global generation of innovations

TNCs have a limited propensity to base their R&D and innovative activities in host countries. The quantitative evidence based on R&D and patents (see Pavitt and Patel, 1999; Archibugi and Iammarino, 1998) indicates that not more than 10% of TNCs technological effort is carried out in host countries. The share which goes to countries outside the Triad is lower than 1% of the total effort of the TNCs based in the developed countries. In other words, LDCs collect the crumbs of the multinationals' innovative activities.

It is rather clear that TNCs do not find it convenient to locate technological activities in developing countries, in spite of the significant wage differentials. We may ask if the reverse would apply to firms in developing countries, i.e. if they find it convenient to locate their R&D and innovative activities in developed nations. There is some evidence that LDCs large companies find it useful to own selected establishments in developed countries since these are instruments to assimilate best-practice techniques that they transfer also to their domestic production. There are some data available for the United States which show that East Asian NICs are beginning to buy establishments in high-tech industries, and that they concentrate their resources in fields, such as computer hardware, telecommunications and electronic components, were they are already strongly specialised at home. This supports the view that technology-intensive FDI by LDCs' companies is mainly meant to reinforce the expertise already existing at home.

Evidence on global technological collaborations

A growing literature has shown that technology agreements have become an important and growing channel to transfer know-how across countries. How are LDCs doing in this area? Narula and Sadowski (1998) report some data on the total number of strategic technology partnering (STD). Nearly 94% of the recorded STP involve countries based in the triad. The share of agreements in developing countries is negligible, and equal to 6.15%. Moreover, 91.24%. of the recorded STP are North-South, involving firms in developed as well as firms in developing countries.

It is also interesting to look at the distribution of STP among developing countries belonging to the various groups. The countries more involved in these collaborations are the East Asian NICs, which alone absorb 58.41% of the agreements (even if their share has slightly declined between the 1980-87 and 1987-94 sub-periods). Equally important and dramatically increasing is the participation of Eastern Europe, which has nearly tripled the share of agreements after the fall of the Berlin wall. Africa and Latin America have a negligible and decreasing participation in STP.

4. Policy Implications: What are the Strategies Open to Developing Countries to Technology and Industrial Development?

The evidence so far reported is incomplete and fragmentary. But the conclusion which is emerging is straightforward: developing countries have a marginal participation in the globalisation of technology according to all the measures taken into account. There is, of course, the significant exception of East Asia's NICs. This group of countries continue to be, even from the globalisation of technology viewpoint, the only case of a successful catching-up strategy in technological capacity as well as in income levels. A few policy implications of the prospect of the globalisation of technology for the strategy of economic development are summarised in Table 3 and below.

The policy implications of the international exploitation of technology produced on a national basis

Developing countries have traditionally been 'invaded' by technology intensive products coming from the Triad countries. The basic disadvantage of this inflows of technology is that it does not allow to build endogenous capabilities and therefore developing countries continue to be dependent on technology coming from developed countries. When developing countries import machinery and equipment they have better opportunities to 'learn by using' (Rosenberg, 1982) and therefore also to start off an up-stream industry of capital goods.
There is, of course, the significant exception of the East Asian NICs which have not imported high tech products, but have also been able, at least in some selected fields and most notably consumers' electronics, to become important exporters in the world economy. The evidence reported above, however, has clearly shown that these countries have also invested massively to develop an endogenous technological capacity.
Developing countries might also search to affirm their productions in developed countries. In selected niches, they have been able to exploit the competitive advantage based on low wages; some Indian firms, for example, have managed to penetrate Western markets selling software services and products. This is a significant and growing industry and it is likely that this has been possible also because of some key characteristics of the industry (such as the standardisation of the product, the low cost of data transmission, the technical possibility of daily exchanges between suppliers and purchasers). But surely this would have not been possible without the existence of specific engineering expertise in India. This example does indicate that if an appropriate market niche is identified and this is combined to existing and potential capabilities, it is possible to open windows of opportunities even in the most developed countries.

The policy implications of the global generation of innovations

FDI is one of the typical case for government intervention; negotiations between the TNCs willing to install their facilities and the potential host governments are in fact common. If we look at the policies adopted by developing countries we will find a variety of strategies. While some countries, such as South Korea and Taiwan, have traditionally preferred to pursue industrial development strategies based on national firms, other countries, such as South Africa, Chile and Brazil, have encouraged TNCs to operate in the country and to bring in their productive, managerial and technological expertise. It seems, however, that governments willing to accept FDI in their territories have not given particular importance to the establishment of R&D and innovative centres.
There are, of course, advantages and disadvantages associated with FDI in the country. The advantages are associated to the acquisition of technological and managerial skills, but at the cost to increase the dependence on the strategic choices of foreign firms and to obstacle the growth of domestic firms. This is a typical case where the economic forces should meet political factors: a strong government is in a better position to negotiate with TNCs and to obtain, as part of the negotiation, that TNCs deploy in the host country both productive and innovative facilities.

The policy implications of global technological collaborations

Cross-border technological collaborations, both in industry and in the academic community, seems to be at the advantage of both the parties involved since they allow to increase learning, to exchange information. Each country has an advantage to become a junction of techno-scientific information.

As in any marriage, on of the partners may get greater benefits than the other. In principle, the partner that has more knowledge has more to teach but is also quicker in learning. Active policies should be attempted in order to capitalise the opportunities associated with collaboration. For what concerns the academic collaborations, it is important to connect them to the productive needs of the country.

So far, south-south bilateral agreements have been neglected. But apparently they might provide a useful strategy to develop appropriate technologies.

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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. Transfer of licenses and patents. Foreign production of internally generated innovative goods .
Global Generation of Innovations	Multinational Firms	R&D and innovative activities in both 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. Production agreements with exchange of technical information and/or equipment.

Source: adapted from Archibugi and Michie, 1995

Table 2 - The Globalisation of Innovation - Implications for the national economies

Categories	Implications for the national economy: Inwards flows	Implications for the national economy: Outwards 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.

Table 3 - Public Policies' Targets and Instruments for the Globalisation of Innovation

Categories		Targets	Instruments
International Exploitation of National Innovations	Inflows	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.
	Outflows	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	Inflows	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 technology strategies and location choices of MNEs.
	Outflows	Strengthening the competitive position of national firms.	Assessment of the need of home-based MNEs to invest abroad in R&D and innovative activites.
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-industral	Allowing the country to become a junction of technical and industrial information. Applying knowledge to production.	Developing infrastructures for techno-collaborations (science parks, consortia, etc.). Promoting University/industry linkages Participation to international organizations for technical and industrial collaborations.

Table 1 - Newly Established Strategic Technology Alliances in Triad and Developing Countries, 1980-1994

	1980-94	1980-87	1987-94
Percentage of Triad STP	93,85	94,51	93,11
Annual average growth rate	4,15	6,05	2,24
Percentage of agreements in developing countries	6,15	5,49	6,89
Annual average growth rate (%)	5,98	7,03	4,93
Percentage of LDCs STP involving Triad firm	91,24	90,29	92,19

Source: Narula and Sadowski (1998).

Legend: LDCs: Less Developed Countries.
STP:Strategic Technology Partnering

Table 2 - Strategic Technology Alliances in Developing Countries by Region 1980-94

	Percentage of alliances 1980-94	Percentage of alliances 1980-87	Percentage of alliances 1987-94
East Asian NICs	58,41	63,95	55,84
Other Asia and Africa	8,84	17,01	5,05
Latin America	4,31	6,12	3,47
Eastern Europe	28,45	12,93	35,65

Source: Narula and Sadowski (1998).