Nanotechnology and Microelectronics:

Global Diffusion, Economics and Policy

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Printed at: Yurchak Printing Inc.

Published in the United States of America by
Information Science Reference (an imprint of IGI Global)
701 E. Chocolate Avenue
Hershey PA 17033
Tel: 717-533-8845
Fax: 717-533-8661
E-mail: cust@igi-global.com
Web site: http://www.igi-global.com

Library of Congress Cataloging-in-Publication Data

Nanotechnology and microelectronics : global diffusion, economics and policy / Ndubuisi Ekekwe, editor.
p. cm.
Includes bibliographical references and index.
Summary: "This book assesses the state of nanotechnology and microelectronics, and examines many issues, such as climate change, trade, innovation, diffusion, etc, with a theme focused on facilitating the structures for the adoption and penetration of the technologies into developing nations"--Provided by publisher.
ISBN 978-1-61692-006-7 (hbk.) -- ISBN 978-1-61692-007-4 (ebook) 1. Nanotechnology. 2. Microelectronics. 3. Technological innovations--Economic aspects--Developing countries. 4. Technology transfer--Developing countries. 5. High technology industries--Developing countries. I. Ekekwe, Ndubuisi, 1973-
T174.7.N37325 2010
620'.5--dc22
2010010146

British Cataloguing in Publication Data
A Cataloguing in Publication record for this book is available from the British Library.

Chapter 4
Collaborations in the Open Innovation Era

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ABSTRACT

Although the impact of open innovation on a global scale on the collaboration between universities and foreign industry is clearly important, empirical evidence from the field is lacking. This chapter investigates the collaboration between Hungarian universities and foreign companies in research and development. The chapter attempts to provide a relevant picture of the research-related linkages of Hungarian universities and foreign companies by employing secondary data processed from various data-banks. The analysis suggests that foreign direct investment and foreign companies play major roles in the internationalisation of research during this second decade of the transition process. Assessing the research and technology products which have originated in university-industry collaboration is no easy task. According to experimental measurements and pilot data-bank, there were more joint publications involving foreign than domestic companies, and the citation value per publication was significantly higher with the former. Data-bank also show that developments in new technology in terms of patent figures rarely involved university-owned or co-owned inventions, although there is some evidence there are more patents which are university-related than owned. Domestic invention and the foreign ownership of patents represent one more sign of Hungarian involvement in global innovation in the development of new technologies.

INTRODUCTION

The new wave of internationalisation is a product of corporate research and development (R&D) activity. The circulation of international knowledge is critical for the development of innovation performance and for the improvement of national competitiveness in the sense that internationalisation widens the access of companies to academic knowledge and research capabilities. In this pro-

DOI: 10.4018/978-1-61692-006-7.ch004

cess, entities in the international business world influence connections between universities and industry on a cross-border basis. An important question facing policy-makers in Science and Technology asks how this kind of internationalisation affects the universities in the academic host country. The contribution - in terms of inventions of universities to innovation and to economic growth may well become outwardly directed. Conversely, however, without such contracts with foreign companies, universities which are not located in an innovative environment have fewer chances to participate in cutting-edge research activities, and any spillover effects may come much later. The ideal balance between inflow (foreign corporate R&D investment) and outflow (the commercial sales of intellectual property or know-how) is a delicate issue for university administrators, for the corporate sphere and for national policy-makers.

In terms of the internationalisation of university-industry linkages, three fields are currently showing ongoing transformation. The first of these is the changing pattern of innovation which affects the ways in which companies outsource R&D and collaborate commercially; the second relates to the enhancement and globalisation of the Third Mission of Higher Education; the third involves the new wave of internationalisation in which companies' related R&D and innovation activities are globalised. At the same time the policies which stimulate FDI are changing, and the new generations of FDI and other policies focus on FDI-led R&D and innovation. (UNCTAD 2001, Kalotay and Filippov 2009, Guimón 2009)

Although the impact of open innovation on collaboration between universities and foreign industry is clearly important, there is a lack of empirical evidence from this field, and this paper attempts to use of the various data sources available and to develop new indicators to analyse Hungarian involvement in the process

The extent of internationalisation, as reflected by foreign ownership, has increased significantly in Hungary over the last decade, and one of the consequences of internationalisation is the changing pattern of university-industry relations. The context of the internationalisation of the relationship is distinctive, given that the proportion of domestic invention registered by foreign companies amounts to some 60%.

Hungarian universities do collaborate with foreign-owned companies located in the country - as with companies based elsewhere - and international partners play an important role in linking universities and industry, quite apart from the national environment, which we can describe as moderately innovative.

Following an overview of transformation (on the basis of the literature) the paper offers a number of facts about general foreign involvement in Hungarian business R&D activities and outsourcing. For this part of the analysis we use official statistics on business R&D expenditure. The third and fourth parts of the chapter briefly describe the relationships of Hungarian universities and foreign companies. These sections attempt to illustrate the internationalisation of university-industry relationships using secondary processing from various data sources.

Two different types of foreign business are examined. The first of these relates to entities which are partly or totally foreign-owned but registered in Hungary and the second to foreign entities which are not registered in Hungary and which are only involved in investing in and purchasing R&D.

To describe and analyse relationships, the paper employs certain input and output indicators. The third part is devoted to those inputs where innovation input is represented by R&D expenditure and the fourth investigates the output side of the process by means of publications and patent data.

The available data allow some debate on the specifics of the internationalisation of university-industry partnerships in transition economies, and the paper provides a better understanding of how the open innovation model works and how this affects the triple helix model.

ONGOING TRANSFORMATION

A global transformation is evidenced by the changing structure of innovation, and we can also see the parallel (and closely related) phenomenon of Humboldtian universities being in a similar state of transformation. The new wave of internationalisation touches both. There is a large quantity of published material covering these related issues, and the next sections highlight the new challenges and some new findings in the literature.

The Changing Innovation Model

In the late 19th century a crucial innovation occurred in the generation of useful knowledge for industry: in-house research and development (R&D) laboratories. At that time, when the first company laboratories appeared, this started the trend towards in-house research and to a closed system of innovation. The companies spent majority of their R&D budget in-house in their own laboratories,–until, in fact, the 1960s. Over this period the innovation process was characterised by the internal generation and use of knowledge within a company and by little or nothing which was purchased or could be termed external knowledge. Practice at the dawn of the 20th century leant heavily towards closed or semi-closed innovation.

Starting in the 1960s, however, the (now traditional) closed innovation paradigm was turned around completely and was replaced by the open innovation paradigm. (Chesbrough 2003, Gassmann and Enkel 2004) These linkages lead to a 'network model of innovation' (Callon 1992), 'distributed innovation processes' (Coombs et al., 2003) or 'open innovation' (Chesbrough, 2003). The common, central idea behind these various terms is that, in a world of widely distributed knowledge, companies cannot afford to rely entirely on their own research, but should, instead, buy or license processes or inventions from others.

Companies are again employing extramural activities. Both needs (faster and more efficient innovation) and opportunities (drastic reductions in transport, communication and co-ordination costs, rapid developments in ICT and for greater codification and standardisation of R&D processes) for open innovation have increased the possibilities for segmenting and dispersing R&D over a number of locations and types of organisation (such as other companies and public research organisations).[1] Mainstream companies are increasingly opening their innovation processes and collaborating on innovation with external partners (suppliers, customers, universities etc.) and there is clear movement towards the greater outsourcing of business R&D - either to other companies or to public research organisations.[2] Companies can no longer survive through their own R&D efforts but look for new, more open, methods of innovation.

The external partners chosen by companies differ according to whether the companies wish to collaborate on research or on development. (OECD, 2008a p. 114.) Even if the majority of outsourced business R&D goes to other companies (OECD 2008b p. 19) the demand for public research organisations such as universities has increased significantly.

In the open innovation system, working within R&D and innovation networks is crucial since these networks can contribute to a rational balance between 'intramural' and 'extramural' R&D capacities and activities. In-house capacities are very important for the selection of external partners, for reinforcing decisions on purchasing new knowledge and technology, and for supporting the application of new technology.

The concept of open innovation is closely linked to national and regional innovation systems which emphasise the inter-organisational linkages for knowledge creation and diffusion.[3] (Lundvall, 1992; Nelson 1993) From this complex system the 'triple helix' model describes the linkages between public and private sectors when university, industry and government work together. (Etzkowitz and Leydesdorff (1997), Etzkowitz (2008).

Changes in Research in Higher Education

The university (and academic research organisations) are crucial actors in the knowledge-driven economy as knowledge-generating agents. In the wider innovation process, they are both sources of basic knowledge and potential partners in the open innovation strategy of companies.

The literature is very rich on the changing model of the university in the late 20th century. (Bonacorsi and Dario 2007, Inzelt 2004, Laredo 2007, Martin 2003, Nedeva 2008, Sanchez and Elena 2006, Varga 2000,). Whilst the term "open innovation" explains why it is important for companies to collaborate with universities and public research organisations, the triple helix model focuses on university-industry-government interaction and partnership and studies their changes. (Etzkowitz and Leydesdorff 2000, Etzkowitz 2008) Those researchers who are studying the Third Mission of universities focus on the questions of why it is important and useful for universities to co-operate.

Changes in the Missions of universities and the increasing importance of the Third Mission clearly interrelate with the open innovation system. Sharing university knowledge with the economy and society has many potential benefits for the actors involved. The Third Mission of universities (following Education and Research) is growing in importance (Gulbrandsen and Slipersaeter 2007, Inzelt et al. 2006, Mollas-Gallart et al. 2002). The results of empirical studies and innovation surveys showed that only a small fraction of companies actively demand universities as a partner in innovation. The importance of universities as knowledge sources for companies depends on the characteristics of the sectors (high-technology, advanced, dynamic), the potential to innovate of companies (radical vs. incremental) and the development level of regions.

The available pool of skilled scientists (a critical mass) also influences the capacity of universities to attract lucrative business to the region. (Dőry 2005, Iammarino and McCann 2006, Varga 2005) Last but not least, the local and national environment of universities (e.g., the level of advancement of surrounding industries, the size of a company, the legal framework and intermediaries) also has an impact on collaboration. (A good collection of case studies was published on the role of intermediaries in the Special Section of Research Policy vol. 37, issue 8, 2008)

The strategy of universities toward collaboration has changed due to changes in the size and structure of public funding - parallel to the increased autonomy of universities. (Laudel 2006), and the importance of valorisation in respect of research results, R&D services and collaboration with companies has consequently increased.

The Third Mission depends upon the configuration of activity at a given university activity, how embedded it is in its particular geographical territory and the national institutional framework.[4] The relations of universities with industry have become a major focus for policy-makers, and among these feature contracts with industry, patents taken out directly by universities and the creation of new spin-off and spin-out firms around a university. Similarly, more and more importance has been given to PhD graduates going into industry. (Laredo 2007)

The role of the university in innovation also has a strong impact upon the nature of the knowledge produced by universities. [5] The increased autonomy of universities, the shift towards competitive funding and the changing demand of industry has had an impact not only on the Third Mission of universities but also on education and research. The Bologna process (three degrees in Higher Education, changes to teaching curricula and the introduction of an internationally accepted credits system) is an important adjustment to the needs of the economy and society by institutions of HE within the context of globalised knowledge-driven economies.

As industry-science relationships become global, universities must compete internationally to attract R&D-related FDI, since partners from industry will not finance research into areas in which they are not interested. The ability of universities to compete at world level as well as to join various international networks is important. In addition to an attractive, FDI-related economic policy, the reform of university systems in general, the previous research performances of universities and their accumulated knowledge and capabilities, together with fostering a critical mass in research fields are basic conditions for upgrading international collaboration.

The New Wave of Internationalisation

International co-operation has become more important for companies over the last few decades (Dunning, 2005) characterised by increased interaction between knowledge and globalisation. In this period FDI flows have increased dramatically and continue to be a driving factor of economic globalisation. Corporate innovation activities are increasingly international and tend to favour open innovation–collaborating with external partners, whether suppliers, customers or universities, to maintain their position at the forefront of innovation, and to have new products or services to market before their competitors. More supply-driven factors, such as R&D, have become important.

From the globalisation of open innovation, companies do expect to remain in the forefront of innovation and to outmatch their competitors in introducing new products to the market.

Although the internationalisation of R&D through FDI is not a new phenomenon, its rapid growth and scope have changed dramatically. (Raymond and Taggart 1998, Cantwel and Molero 2003, Narula and Zanfei 2005, Foray 2006) The purchase or outsourcing of R&D (whether domestically or internationally) is now a serious complement to in-house R&D as a part of corporate innovation strategy. (OECD 2008b, EU 2005) The observation of Pavitt (1997, 2002) is still valid–i.e., that a location is attractive for foreign R&D investment if it has a good S&T base (an excellent, or good centre of knowledge, a large pool of skilled S&T workers) and if it provides opportunities to acquire R&D conducted by other companies or institutions and offers more rapid commercialisation.

Traditional cross-border R&D sought to *adapt* products and services to the needs of host countries and to support foreign investors' local operations, and so it was mainly demand-driven. Nowadays, multinational companies (MNCs) seek not only to exploit knowledge generated at home, but also to source technology internationally and to generate new knowledge in other countries - which is why MNCs need access to highly skilled scientific personnel and to tap into worldwide centres of knowledge. (Edler et al. 2002, Edler 2008, Inzelt 2008b, Taggart 1998) More and more companies are responding to increasing global competition and raising R&D costs by internationalising R&D along with other knowledge-intensive corporate functions.[6]

FDI plays a major role in the internationalisation of R&D, and MNCs are the main actors. The literature relating to the internationalisation of innovation systems, which is overviewed by Carlsson (2006), regards inward R&D-intensive FDI as a powerful mechanism of international technology transfer. This mechanism can enable host locations to integrate more advantageously in global value chains. Generally, inward FDI acts as a channel for knowledge-flows and provides opportunities for learning in domestic companies, for establishing regional networks and for involving other foreign- controlled companies.

MNCs have increasingly moved R&D activity across borders within their global value chain and rely on outside innovation for new products and processes. Large companies (mostly MNCs) increasingly adopt innovation networks which link networks of people, institutions (universities, gov-

ernment agencies and other companies) in different countries to solve problems and produce ideas. (Cook 2005) These kinds of internationalised networks generate radical innovation.

Internationalisation relates more to larger companies than to smaller entities and it is more prevalent in certain sectors. Open innovation depends on the technological and industrial context. (Chesbrough and Teece 1996, Gassmann 2006) According to UNCTAD (2005), the activities of the MNCs which spend the most on R&D are concentrated in information technology (hardware), the automotive industry, pharmaceuticals and biotechnology, and in the electronics and electrical industries. OECD adds aviation and aerospace to this list (2008a p. 35). These industries account for over two-thirds of R&D by the world's top 700 spenders (OECD 2008b p.20-21). And so companies or universities active in these fields have a better chance to collaborate internationally than others.

The globalisation of industry-science relationships is also reshaping the triple helix model. (Etzkowitz 2008)

SOME FACTS ON FOREIGN INVOLVEMENT IN HUNGARIAN R&D ACTIVITY

Since the beginning of the transition period, Hungary has attracted a considerable inward flow of FDI and is a typical host country for inward FDI. In 2005 its stock was 56% of GDP, rising to nearly 66% in 2007 - one of the highest levels of foreign ownership in OECD countries. (OECD 2008c, p. 64) Between 1989 and 2008 cumulated FDI per capita in Hungary amounted to US$ 5,314 - third among the countries of Central and Eastern Europe (CEECs), following the Czech Republic (US$ 6,954) and Estonia (US$ 6,749) (EBRD 2005)

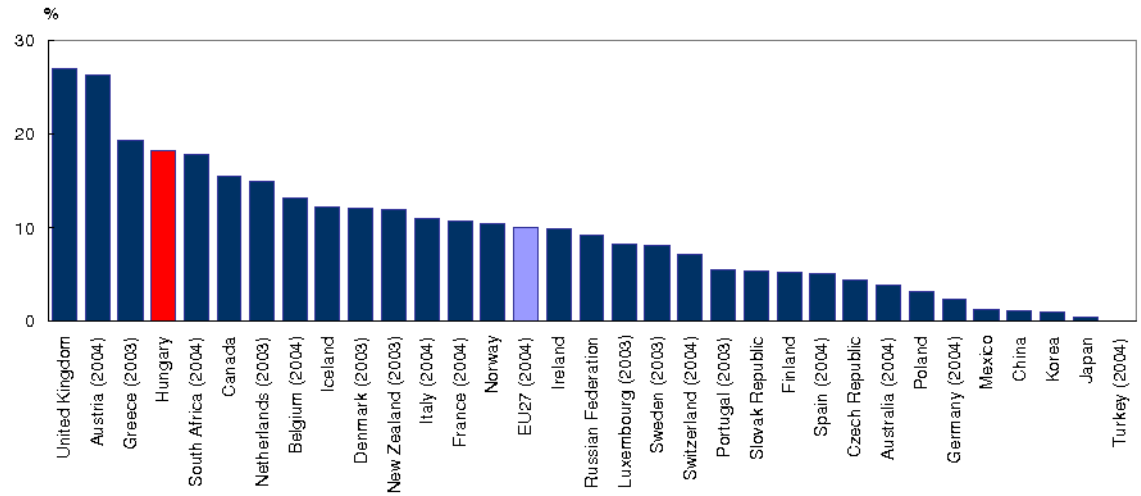
Hungary, as a small country, is more dependent on international flows of knowledge and capital than are larger countries with large internal markets for R&D and innovation. Hungary employs the newest generator of FDI policy that focuses on FDI-led R&D and innovation. In the early 1990s market-based privatization was the main incentive of foreign investment.

No special permit is required to establish a business enterprise in Hungary. Foreign nationals either naturals or legal entities can found companies in Hungary. The only requirement is that the headquarters of such companies must be located within Hungary. Any kind of investors such as foreigners can enjoy the development-tax allowance. That may be utilized for ten tax years following the completion of the development project. Since 1995 Hungary has devoted special attention encouraging foreigners to invest in R&D in Hungary. Hungarian FDI policy backed up with R&D and innovation policy for attracting foreign investment in RDI. These policies together are forming third generation of FDI policy (FDI-led R&D). It is not surprising, therefore, that Hungary should encourage not only general foreign investment but also foreign investment in R&D.[7] The rationale behind this is that globalisation and open innovation provide the country with access to research and innovation networks which will accelerate its own development and better exploit its capabilities. A further assumption is that collaboration in the R&D stage of the value chain makes foreign investment more durable. A long-lasting relationship is an important element in improving competitiveness.

The ratio of Gross Domestic Expenditure on R&D (GERD) to GDP is still under 1% in Hungary, although the proportion of business-funded R&D increased between 1995 and 2005 (OECD 2007, p. 69 and p. 168). In 2006 the ratio of business-funded R&D to GDP was 0.48%, far below the OECD average of 1.56% (OECD 2008c. p. 81.) and also well below the EU's Lisbon targets.

In Hungary, foreign-origin funding for R&D as a percentage of business-funded R&D is, at 18%, significantly above the EU-27 average of 10%. This is also true of business-funded R&D

Figure 1. R&D funding from abroad



Source: OECD STI Scoreboard, p. 169

in the Higher Education and Government sectors. (Figure 1)

The R&D potential of FDI-funded companies differs from that of domestically owned entities. The indicators give an interesting picture of the innovation potential of domestic and foreign-owned firms, and official statistics provide useful information for such an analysis. The Hungarian Statistical Office groups business founders in 5 categories, which we form into two main groups: (1) the '*domestic business'* group (domestic private business, state-owned and local authority-owned) and (2) the '*domiciled, foreign-owned business*' group (businesses fully- or majority-owned by foreign interests).

As Figure 2 illustrates, of the R&D spending companies only 13% were domiciled foreign-owned. In 2007 these financed 67% of business R&D expenditure and employed 51% of scientists and engineers. R&D expenditure per R&D employee was significantly higher than in domestic companies and the number of R&D personnel per unit was also much higher.

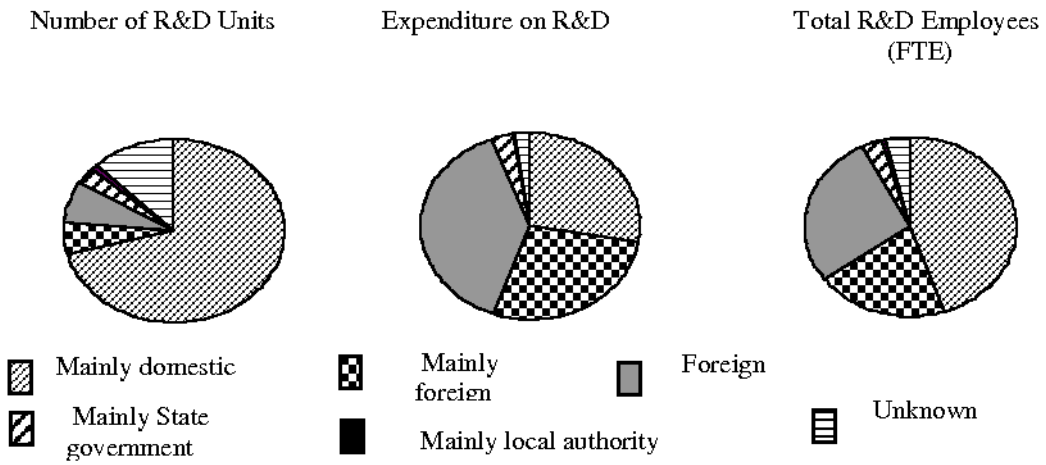
As large companies tend to be foreign-owned, they spend disproportionately more on R&D than do domestic firms, and so, among the R&D-spending companies, MNCs have a particular significance.

The overwhelming role of foreign MNCs in Hungarian R&D has raised the issue of the dependence and vulnerability of the local R&D base. Conversely, the demand of MNCs for R&D plays an important role in preserving and developing R&D capacities and internationalising these activities.

As mentioned earlier, globally open innovation varies by industry. The ratio of outsourced cross-border R&D to total expenditure is more characteristic in certain industries, and the internationalisation of the main R&D-spending MNCs is concentrated on a few sectors. Consequently those companies or universities active in the globally open innovative sectors may be targeted more frequently than others by foreign investors to collaborate internationally in R&D.

Those industries in which the foreign R&D spending of MNCs is concentrated we can refer to as *global R&D spending sectors*. These include the IT, automotive, pharmaceutical, biotechnology, electronic, electrical and aviation and aerospace industries–although the composition of industry varies by region and country.

Figure 2. Key R&D data by company ownership



Source: HCSO, R&D Report, 2007

In this context various questions arise, one of which asks how we should characterise the R&D expenditure of the foreign global R&D spending companies if the difference between these and other industries is so clear. A further question asks how purchase and outsourcing of R&D vary according to industrial sector and ownership. In our attempt to examine this issue, we utilise normal R&D survey data, two types of which are significant for us: total R&D expenditure and the proportion outsourced.[8] From the HCSO databank, we selected those industrial sectors which are recognised as global spenders on R&D and segregated the remaining R&D spending sectors into another group. (Table 1) These data give a picture of outsourcing potential which, to some extent, reflects Higher Education, although the data are not sufficiently detailed to assess the real demand of companies for Higher Education.

Table 1. Business R&D expenditure by sector, 2007 (%)

Sectors	Total R&D expenditure			Outsourced R&D expenditure		
	Foreign	Domestic	Total	Foreign	Domestic	Total
Main global R&D spending sectors	75,6	31,2	65,2	96,1	24,3	89,1
Pharmaceuticals	23,9	17,1	22,3	5,4	12,4	6,1
IT	0,5	8,4	2,3	0	10,7	1
Automotive	48,3	0,9	37,2	90,3	0,4	81,5
Electrical/Electronics	2,9	4,8	3,4	0,4	0,8	0,5
Remaining R&D spending sectors	24,4	68,8	34,8	3,9	75,7	10,9
Total	**100**	**100**	**100**	**100**	**100**	**100**

Source: HCSO data-bank, compiled by Zsuzsanna Szunyogh and the author

Note: IT (3002, 7210, 7221, 7222, 7230, 7250, 7260); Automotive industry: (3410, 3420, 3430); Pharmaceuticals and biotechnology (2441, 2442); Electronics and electrical industry (3110, 3120, 3130, 3150, 3161, 3162, 3210)

In Hungary, the main global R&D spending sectors account for two-thirds of business R&D expenditure, and, in the foreign ownership group, no less than three-quarters (Table 1) This sectoral structure is even stronger if we are focus on outsourced R&D, where 96% relates to foreign-owned companies in global R&D spending sectors, the vast majority of which (90%) comes from the automotive sector.[9]

It is evident that the internationalisation of business R&D in Hungary generally follows global trends, and, if we focus on the outsourced R&D proportion of global R&D spending sectors, it is much higher (50%) than for the remaining R&D sectors. In accordance with international trends, partly or totally foreign-owned companies outsource much more in global R&D spending sectors (55%) than do those mainly domestically owned (12%). The opposite trend is visible among the remaining R&D spending sectors. (Table 2) These figures further demonstrate that the internationalisation pattern of business R&D in Hungary is close to the global trends, demonstrating that collaboration serves global open innovation.

The breakdown of global R&D spending sectors shows strong concentrations. The sector shows that the outsourcing activity of foreign-owned companies is more intensive in foreign-owned companies - in the automotive (80% vs. 7%) and in the electrical and electronics (6 vs. 3%) industries. Domestically-owned companies outsource a somewhat higher proportion of their R&D in the pharmaceutical and IT industries - totally against international trends. Foreign companies outsource less than 2%, whilst, for domestically-owned firms the figure approaches 20%. Further investigation is needed to identify the reasons for this deviation and it would also be useful to examine the content of R&D activity.

Official statistics cannot provide any figures relating to the number of universities who are active in performing outsourced R&D. There are, however, a few items of indirect information. One important feature is that the proportion of company- financed R&D to total R&D performed in the HE and government sectors is much higher in Hungary, (11%) than in the EU-27, (6.4%) whilst the ratio of business R&D expenditure to GDP is lower than the EU average. One further fact to be mentioned is that the investment in R&D by foreign-owned companies in Hungary has its own significance. As foreign business is responsible for the lion's share of Hungarian business R&D, we can assume that FDI-related R&D is important for Higher Education Institutions (HEIs)–or at least in global innovation-related fields of science. We

Table 2. Business outsourced R&D in Hungary by international character of sectors 2007

Sectors	Foreign	Domestic	Total	Foreign	Domestic	Total
	Outsourced R&D to total R&D expenditure (%)			Outsourced R&D to in-house R&D expenditure (%)		
Main global R&D spending sectors	55,1	12,0	50,3	122,8	13,6	101,1
Pharmaceuticals	9,8	11,1	10,0	10,8	12,5	11,1
IT	1,8	19,5	16,7	1,8	24,3	20,0
Automotive	81,1	6,8	80,6	427,8	7,3	416,6
Electrical/electronics	6,3	2,6	5,1	6,8	2,7	5,4
Remaining R&D spending sectors	6,9	16,8	11,5	7,4	20,3	13,0
Total	**43,4**	**15,3**	**36,8**	**76,6**	**18,1**	**58,2**

Source and note: see table 3.

attempt to investigate this issue further using new data and indicators.

COLLABORATION BETWEEN FOREIGN COMPANIES AND HUNGARIAN UNIVERSITIES

Companies commonly seek partners for collaboration in development, (industrial partners, clients, suppliers). (OECD 2008a p.91) Universities are natural partners for profit-oriented strategies although less important for asset-exploiting strategies in many countries. Whether we approach industry-university collaboration from the perspective of the company or of the university, both prefer to collaborate with one another in the pursuit of profit

According to the experience of advanced countries or regions, companies search for universities which could be potential partners in research collaboration, whilst in less advanced countries (or regions), where appropriate innovative business partners are rare and there are limited opportunities for foreign investors to find business partners for innovations, this shortage may lead to a division of collaboration among a handful of universities prominent in research and industry. In less innovative circumstances, the second-best solution for innovative business is to contract with universities not only for profit-seeking but also for asset-exploiting R&D tasks. For foreign investors, universities may to some degree be a substitute for non-existent local innovation actors and can also act as magnets, attracting attention to the region. If the local ecology is not rich enough, internationalisation reshapes the university-industry relationship.[10] (Inzelt 2004, Inzelt 2008a, Kállay and Lengyel 2008, Inzelt and Csonka 2008)

Companies build especially close relationships with certain universities, and the academic excellence of universities and public research laboratories attract the R&D departments of large firms. The attractiveness of a university to external actors depends on many factors such as the university's research potential, the way in which the university is equipped to develop knowledge jointly with companies and the capabilities for technology transfer offices. Another crucial factor is "subject-mix" and the universities' existing research fields, since open innovation is more frequently found in those industries which target faculties in their own fields.

Contracts with Industry

As discussed in the literature, there are many dimensions and forms of collaboration. (Gulbrandsen and Slipersaeter 2007, Inzelt et al. 2006, Molas-Gallart et al. 2002) So-called purchasing-based innovative companies interact with Institutions of HE as they purchase inputs for their innovation process. Companies active in creating new knowledge collaborate on research. These companies establish partnerships to innovate jointly with a common goal in view. (OECD 2008a, p. 22) These contracts may cover various forms of relationship. Contracts with industry cover an institution's revenues from private companies for undertaking research, providing research services or for carrying out testing for industrial partners. The contracts may have a 'soft' dimension: large companies may pay (directly or through the university) faculty members' membership fees to professional associations, the cost of travel to participate in conferences, or funds to cover the cost of professional publications. (Inzelt et al. 2006) Contracts may also include several other activities besides research and research services. For example, PhD students might be supported by industry, or a company may contract with an university to provide training courses for their employees.

From these linkages we focus only on those which are R&D-related. To demonstrate international collaboration, we employ one of the input indicators of innovation practice - R&D expen-

diture funded by the business sphere. Two types of output indicator are employed: scientometrics which are generally used for measuring scientific performance and patent indicators to characterise technology creation. Indicators are designed to measure collaborative performances.

Most relations between Hungarian universities and companies are covered by research contracts and we can examine some official statistics concerning the role of business in funding university research.

In financing Higher Education R&D, the major source is still the government sector. (Table 3) Business represents a smaller (but growing) proportion. In 2007 business financed 14% of total HE expenditure on R&D (HERD). This figure was similar in 2005, although it had been only 6% in 2000. This increase indicates that more and more national (and EU) programmes have initiated public-private partnerships encouraging private business demand. These incentives have affected the 'contracts with industry'. (Table 3)

Companies which are working in Hungary (domestic and domiciled foreign firms) financed 2% of HERD in 1995 when FDI scarcely featured in R&D. Around the turn of the century business became much more important in financing (12% in 2002) as FDI-led R&D activity reached the universities.

Investigating the funding structure of HERD, we can also see another type of foreign corporate player: some foreign companies with no production or commercial investment in Hungary are contracting with universities. Since 2002 these companies have provided 0.2-0.3% of HERD. This tiny percentage is easy to overlook, but the source has its own importance for the university departments involved and for the field of science. The source represents an opportunity to collaborate in the development of advanced technology and to break into the network of pioneering companies since companies target partners from among the cutting-edge departments of universities.

As the official statistics cannot provide information on the owners and origins of those companies funding Higher Education, we must employ another database to learn more about foreign HERD sources. An administrative databank at the Ministry of Education which existed between 1995 and 2005 contained detailed information on various research contracts of universities.[11] (See the description in Inzelt 2004, p. 979) Employing the figures and value of business funding can provide information on the size of the business sources which were attracted. The main advantage of this databank compared to official statistics is that it allows us to break down university-industry research contracts according to the owners and origins of business organisations for so-called large income contracts, meaning that the sum of the contract exceeds HUF 5m (€19-20,000). HE Institutions have many contracts below this

Table 3. Distribution of the sources of HERD (%)

Funding sources	1995	2000	2002	2004	2006	2007
Government	89.8	85.8	83.8	80.9	77.1	76.8
Business (domestic and domiciled firms)	2.1	5.7	11.8	12.9	13.0	13.7
Non-profit	-	1.0	0.8	0.6	1.7	1.8
Foreign sources	3.8	5.4	3.7	5.7	8.2	7.7
Foreign firms working abroad	-	-	0.3	0.2	0.2	0.3
Others	4.3	2.1	-	-	-	-
Total	100.0	100.0	100.0	100.0	100.0	100.0
Source: compiled from HCSO databank, June 2009						

threshold, but information on them is either missing or not detailed.

To investigate the origin of large contracts and of contracts with foreign industry we selected 12 Hungarian universities (6 large and 6 in the medium-to-small bracket). The main selection criterion was good research performance as demonstrated by publications. (The 12 provide 90% of ISI publications.)[12]

The so-called foreign partners of universities belong to two different groups: (1) partly or totally foreign-owned domiciled firms and (2) foreign firms with no local manufacturing or service activity. Categorisation was carried out manually.[13]

Between 2000 and 2005 more than 50% of contracts (by number) and two-thirds of business-derived income came from foreign-owned and foreign-located companies. Table 4 shows contracts with industry according to the origin of the commercial partner.

Similarly to the general picture given in the previous section on domestic and domiciled foreign firms, the number of contracts with domestic firms is high, but University income from contracts is lower from this source. The average income per contract with domestic companies was HUF 23.5m, a sum which was 54% higher when foreign-located firms were involved and 66% higher in the case of contracts with domiciled foreign-owned firms.

Available data do not allow us to separate these contracts by purchasing-based activities or collaborative relationships. However, the importance of the university as a source of knowledge is different for the two types. According to anecdotal evidence, the bulk of contracts are more purchasing-based than collaborative in character.

Further information is needed to assess the impact of contract research on HE research activities and the innovativeness of companies. For example, if we wish to know the aims of university-industry collaboration, the character of the knowledge purchased, the information needed, the number and total value of contracts according to purpose we need much more detailed information. It would be very useful if we could break down the number and the value of contracts by their aim (research, research services, training, consultancy and expert advice to industry, university faculty development, supported research chairs) and by types of partner (MNCs, large companies, SMEs) and investigate these data on the level of faculty, university and scientific field. Further useful information would be the size and level of internationalisation of the collaborating firms.

In addition to information on partner companies, it is also important to learn the capabilities of universities to produce useful knowledge for the outside world and also to understand university departments and which fields of science are best

Table 4. Overview of contracts with industry, 2000-2005 (12 universities)

Owners and Origin	No. of Contracts	Income	Income / contracts	Distribution by	
				No. of Contracts	Income
		M HUF			
Mainly Domestic, Private	143	3367.4	23.5	47	36
Domiciled Foreign (majority shareholding)	66	2578.6	39.1	22	28
Foreign-located	92	3320.6	36.1	31	36
Total	*301*	*9266.6*	*30.8*	*100*	*100*

Source: IKU's compilation from the databank of the Ministry of Education (and Culture)

Note: the table contains only those contracts whose total value exceeded HUF 5m. Each university has had many other minor contracts.

suited to collaboration with business. We need further statistics in all of these areas.

Information on the duration of contracts and renewed partnerships is also important. The regular appearance of a partner as an outsourcer or collaborator in joint research is a sign that the partner is innovative and has a strong motivation to acquire new knowledge regularly. Although longer contracts can provide more stability in research agendas and in financing, the actual duration of contracts may well differ from that originally contracted. In Hungary, as in several other countries, the regulatory framework may make it more advantageous for industry to break comprehensive collaboration down into smaller units and to renew contracts annually. This means that "cleaned data" are important if we are to be able to identify the real duration of a contract -and also that "renewed partnerships" may be less significant.

MEASURABLE OUTPUT FROM COLLABORATION

Collaboration with industry has a variety of output. In addition to publications and patents there are other valuable products of collaboration such as grey literature and confidential expert reports to industry. No systematic information is available on these categories.

The most traditional output indicators are scientific publications and patents. These are discussed in this section and have also been developed further by disaggregating them in order to gain a closer insight into the main products of collaboration. Joint university-industry publications are characterised by scientometric indicators and data extracted from the "Web of Science" on Hungarian universities. For an analysis of co-patenting and collaboration leading to patenting, we employed two data sources: nationally registered patent data and the OECD Triadic Patent Family -and we extracted data for Hungary from both to create indicators.

Co-Publications

Scientific publication has intensified worldwide. The share of co-authored papers by industrial and academic scientists grew rapidly. (Calvert and Patel 2002, Hicks and Hamilton 1999) Indicators of international co-authorship (the number of articles by two or more authors from different countries) point to increasing cross-border collaboration, and international co-authorship has increased in most countries in the past decades. (Glänzel et al. 2006) The vast majority of these publications have originated from academic circles in different countries, although an (as yet, much smaller, but growing) number of internationally co-authored papers come from international collaboration between academia and industry.

In Hungary changes corresponding to these world trends and the number of internationally co-authored papers are increasing significantly. This process was supported by the transition, a process which opened up the country in the '90s. During the second half of this transition period (2001-2005) the proportion of internationally co-authored papers seems to have stabilised.

The total number of Hungarian scientific publications (according to WoS ISI data) has increased more than 30% whilst the parallel figure for internationally co-authored papers was slightly below 30% during the period investigated at the selected universities.[14] Increased domestic and international co-authorship indicates the crucial role of interaction among researchers with different backgrounds for diversifying their sources of knowledge, and internationally co-authored papers accounted for two-thirds of all scientific publications.

As the publication pattern varies greatly according to the fields involved, we divided universities into three subgroups: (1) Universities with Faculties of Medicine, Universities with Faculties of Technology and (3) Universities with Faculties other than Medicine and Technology (= Others) (Table 5)

Table 5. Ratio of co-authored scientific articles to total publications (12 universities, 2001-2005, %)

Universities with Faculties of	Total		Total international		With international business		Growth rate of international business co-authored publications
	co-authored papers						
	2001	2005	2001	2005	2001	2005	2005 to 2001
Medicine	89.6	88.7	66.8	63.7	2.0	2.3	1.48
Technology	99.5	98.6	61.7	58.0	2.2	3.0	1.44
Others	95.9	97.2	61.4	65,1	1.5	0.6	0.67
Total (12)	92.7	92.4	64.7	63.4	1.9	1.9	1.31

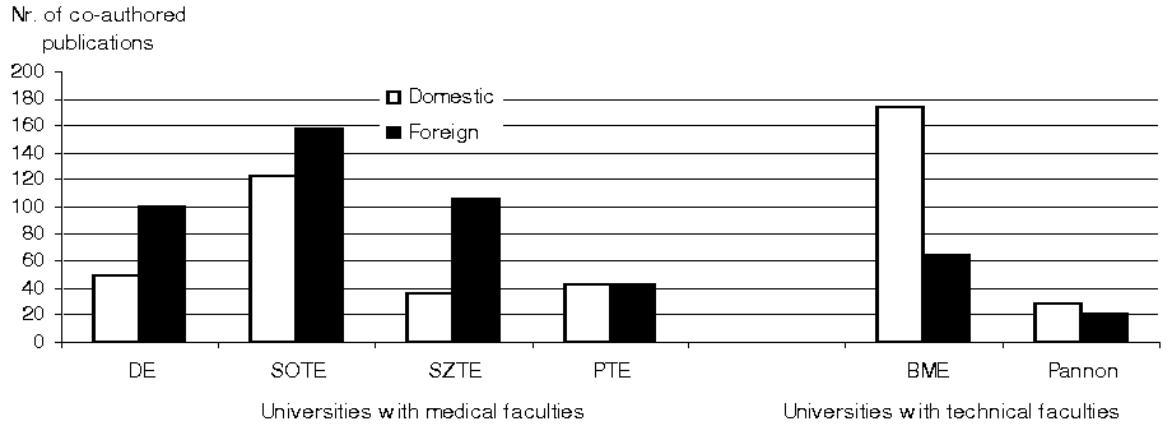
Source: extracted from background documents to Inzelt and Schubert. 2009

Papers co-authored with international business (foreign-located companies) represent a minute fraction (2%) of the total of scientific publications. The characteristics of this minor group are investigated here when a foreign-located company is the co-author. The importance of papers co-authored with business is the generation of useful knowledge for practice and for knowledge diffusion.

Of the 12 universities examined, it is mainly those with Faculties of Medicine and Technology who regularly produce joint publications with industry, and, of these, it is those with Faculties of Technology who more frequently (albeit not by a large margin) publish in collaboration with international business than those with Faculties of Medicine. It is, however, remarkable that universities with Faculties of Medicine have been able to increase their number of joint publications with international business faster than those with Faculties of Technology. At the same time the ratio of internationally co-authored papers is not only lower at universities without these specific Faculties but significantly so (in favour of academic partners).

Figure 3 compares university-industry co-authored papers by domestic and foreign business partners.

Figure 3. Co-authorship between faculty members and industrial researchers by number of co-authored publications by origin of firms (2001-2005)



Source: extracted from background documents to Inzelt et. al. 2009

The number of co-publications involving foreign business partners was larger at 3 of the 4 universities with Faculties of Medicine than with domestic partners. In the case of universities with Faculties of Technology, the situation was the opposite: the number of domestic co-authored papers was much larger. We may assume that foreign-owned, domiciled firms (FDI-led) are among the important co-authors with universities with Faculties of Technology, but, in the absence of precise data, we can only guess the FDI-led R&D role in 'domestic' co-authored papers. In any case the output of universities with Faculties of Medicine supports the hypothesis that foreign companies are dynamos of university-industry collaboration in a less innovative environment.

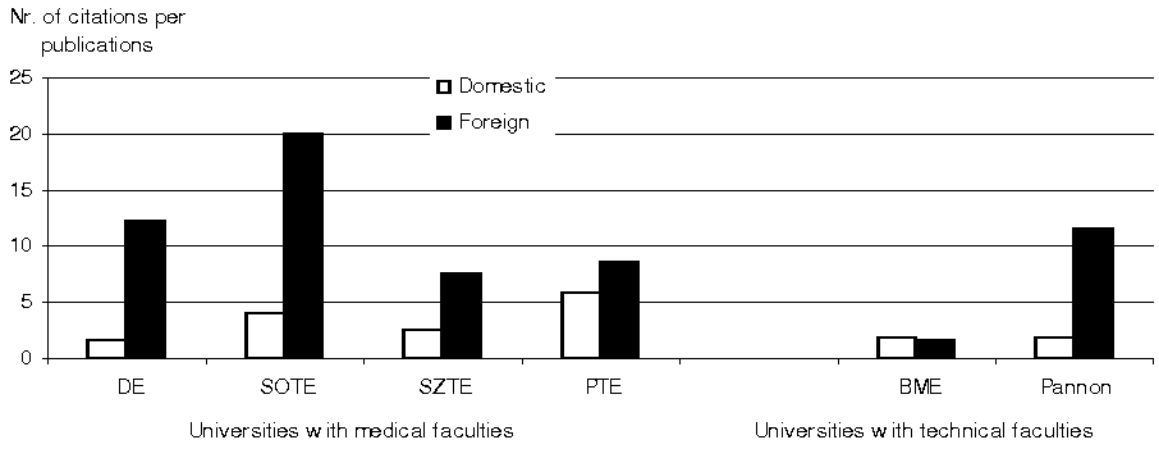
To judge innovation potential embedded in scientific results and the robustness of research findings, it is important to know the value of new knowledge originating from papers co-authored with industry. For this evaluation the most widely used indicator is the citation index, which is a guide to the scientific importance of the paper.[15]

According to our earlier study on Higher Education publications (Inzelt et al., 2009) international co-authorship has positive effects on the citation rate of publications. This general picture is true if we focus on co-authorship with industry. (Figure 4)

Figure 4 illustrates the citation performances by domestic and foreign co-authored publications. Of the 6 universities investigated, 5 have a higher citation rate per publication where co-authors were foreign rather than domestic companies. This picture varies from the norm at Hungary's largest University of Technology. (Figure 4)

As Figure 4 illustrates, except for the largest university in Hungary (comprising several Faculties of Technology), the other 5 universities have papers (co-authored with international business partners) which are heavily cited. This figure suggests that an international business partnership has a positive effect on the citation-level of publications. This general picture may not only be a sign of the novelty value of the papers, but of the greater weight accorded to foreign partners in the

Figure 4. Citations per publication of senior academics' and industrial researchers' co-authored papers by company origin (2001-2005)



Source: extracted from background documents to Inzelt et. al. 2009

scientific world, or, again, of scientific marketing capabilities which are stronger than the domestic.

Invention and Patent Application

Cross-sectoral (referring to the business and academic sectors) collaborations in inventions are crucial for the capitalisation of knowledge. Universities as a site of invention are subject to their individual national and internal regulations on patent ownership. They differ not only by their patent regulations but in their capabilities to manage intellectual property. The various national innovation systems usually offer 3 main approaches to patent ownership for universities (Inzelt et al. 2006):

- Institutional ownership
  a. University-owned
  b. Jointly-owned by university and other organisation(s)
  c. Owned by research funding company or agency
- 2. Individual ownership
  a. Patent owned by inventors (Faculty members)
  b. Jointly-owned by academics and other individuals or organisations.
- 3. Mixed individual and institutional ownership (see all above)

From this classification it can be seen that university-related inventions are becoming university-owned patents in the case of institutional ownership (1a and 1b), and so, when investigating university patents it is worthwhile distinguishing between two categories:

1. Patents *owned* by the university
2. Patents *invented* (or co-invented) in the university (so-called indirect university patent)

In the first category are those patents for which the patenting university applied alone or with co-applicants and became the owner or co-owner of registered patents. The second category contains those patents which are not owned by the university but where all or some of the inventors are Faculty members.

The difference in size of these two categories is quite significant. If the regulations were to permit ownership of the patent by the university, by the company or by the inventors as individuals, the number of patents produced by the university could be 10 or 20 times higher than the number of university-owned or co-owned patents actually shown.

The first category may be calculated from patent statistics, although it is more difficult to obtain reliable data on the second category. (See the discussion in Inzelt et. al. 2006, pp. 139-147)

According to international experience, the increasing volume of R&D investment abroad is matched by the increasing importance of the home and host country's role in patenting. However, the increasing volume of FDI-led R&D investment has raised important questions for both home and host countries where patents are being applied for.

The OECD distinguishes 3 important categories of patenting international R&D activity; these help to characterise cross-national relationships between inventors and applicants/owners. (OECD STI Scoreboard 2007, p. 162, 164, Guellec, D. and van Pottelsberghe de la Potterie 2001)

1. Cross-border ownership: Country of residence of owner and inventor differs. (e.g. multinational conglomerate and foreign subsidiary);
2. Foreign ownership of domestic invention: Compared to the total number of patents, the indicator expresses the extent to which foreign firms control domestic inventions and reflects the importance of a country's inward R&D investments;
3. Domestic ownership of inventions made abroad refers to the property of a country, but requires that at least one inventor be

located in a foreign country out of the total number of domestic applications. This indicator evaluates the extent to which domestic firms control inventions made by residents of other countries.

We may add another category: (4) Joint ownership of co-invention when domestic and foreign actors together own the patent.

In the context of Hungarian universities and foreign firms the second type is most marked, and the others scarcely exist.

Measuring the technology innovation performance of Hungarian universities is not an easy task even if we do not focus on internationalisation.[16] Hungarian HEIs belong to the third group of patent ownership by universities (i.e., mixed individual and institutional ownership). Hungarian universities rarely own the inventions of their faculty members.[17]

Data is available on university-owned patents but not on indirect university patents. The latter still has to be created.

University-Owned Patents

The share of patents filed under PCT and owned by universities is 1.2% in Hungary while the OECD average was 4.3 and the EU average 3.1% in 2002-2004. (OECD 2007, p. 75.)

Among the main reasons for the low level of Hungarian university-owned patents were the lack of resources for patenting, the poor management of inventions and the confused regulations on university-related intellectual property in effect prior to the enactment of new legislation in 2004-2005.[18]

Taking into account the small number of university-owned patents, it is not surprising that only two applications by joint university-foreign-owned companies (registered in Hungary) can be seen in the Hungarian Patent Office databank for the period between 2000 and 2007. In respect of the patent performance of universities, the revenues from the licensing of patents were almost negligible.

Indirect University Patents

Knowledge of the university-linked inventions owned by others is important for several reasons. The information on indirect patents gives a more reliable picture of the technology creation capabilities of universities than that on owned patents if the ownership is not strictly institutional. In addition, information on the organisations of inventors and of applicant organisations helps us to understand collaboration linkages.

Among the OECD's 36 members, Hungary ranks fourth in terms of the foreign ownership of domestic inventions, a proportion which is relatively high in Hungary compared to other OECD economies. Almost 60% of domestic inventions were under foreign ownership in 2003. This proportion was around 30% in 1993. (OECD 2008b. 33-36)

Universities do not differ from this general picture. Although there are no data on the foreign ownership of domestic university inventions, all indirect information suggests that foreigners own a considerable part of domestic university inventions, even if they covered only the minor part of the research expenditure.

Due to the shortage of data on indirect university patents, we utilise data on the cross-border ownership of inventions. This method is acceptable as a first attempt at measuring, and we can assume that the university picture on inventor-applicant relationships is very close to the general picture.

For our analysis of the inventor-applicant relationship we used the OECD developed *Triadic Patent Family*[19] which has been available since 2008. The advantages of this data-set '... only patents applied for in the same set of countries are included in the family ... patents included in the family are typically of higher value, as patentees only take on the additional costs and delays of extending protection to other countries if they deem it worthwhile.' (OECD 2009, p. 71-72)

This international resource of patent statistics can provide information only on relationships between Hungarian inventors and foreign applicants and not specific information on relationships between universities and international actors.[20]

The Triadic Patent Family shows 58 patent applications listing Hungarian inventors for the period 2000-2004.[21]Table 6 gives an overview of Hungarian related patents in the Triadic Patent Family.

There were no Hungarian universities among the applicants.[22] Neither academic nor corporate collaboration produced a Hungarian university as a co-applicant. Foreign laboratories were characterised by the foreign ownership of domestic inventions (the number of patents relating to domestic inventions and owned by non-residents). Among the applicants involving Hungarian inventors, 2 foreign universities (USA) and 2 foreign laboratories (USA and France) are found. When US universities were the applicants, the inventors were from both countries (Hungary and the US) as the invention was based on collaborative research.[23]

Two-thirds of the inventors were Hungarian when the applicant was a foreigner. The majority of applicants were foreign companies (36), and, out of this group, the cross-border ownership of the invention is clear in the case of 14 foreign companies (all inventors are Hungarian but the applicants belong to different countries). The majority of applicants are foreign investors in Hungary and, in these cases, some collaboration can be presumed between the foreign-owned company and faculty members. The other 22 applicants list both Hungarian and foreign inventors, signifying cross-border ownership based on cross-border collaboration.

Although we do not have exact figures on domestic university inventions controlled by foreign firms, all indirect information suggests that foreigners control a considerable part of the universities' inventions, even if foreign funding only covered a small fraction of the research costs.

In Hungary, as well as in many European countries, specific measures are important to protect the proprietary knowledge created by domestic universities. In addition to the low level of patenting activities in universities, the weakness of intellectual asset management may encourage companies to become applicants for patents rather than to purchase licences. The effect of new regulations (2004, 2005) on managing intellectual

Table 6. Hungarian related inventions, by applicant, in the Triadic patent family (2000-2004)

Applicants	No. of Applicants by origin of Inventor			Number of Inventors		
	only Hungarian	Hungarians & foreigners	Total	Hungarian	Foreigners	Total
Institutional applications						
Foreign university		2	2	4	12	16
Foreign research laboratory	1	1	2	4	3	7
Foreign companies	14	22	36	112	51	163
- with Hungarian location	11	10	21	70	23	93
- no Hungarian location	3	12	15	42	28	70
Mainly Hungarian-owned	12	1	13	90	2	92
Hungarian laboratory	1	-	1	6	-	6
Individual applications						
Individuals	1	3	4	10	6	16
Total	29	29	58	226	74	300

Source: compiled on the base of OECD Triadic Family Patent Databank

property by universities and interactions with firms in this field will be measurable in the years to come, and, one day, universities may become, along with foreign companies, co-applicants in respect of their own inventions.

FINAL REMARKS

Globalisation has reduced the barriers to entry into global networks and has also created opportunities for new players to enter. The penetration of FDI-led R&D in Hungary has involved Hungarian universities in international university-industry collaboration, and, as foreign business holds the lion's share of Hungarian business R&D, it is clear that FDI- related R&D is important for HEIs, at least in those fields of science relevant to global innovation.

In accordance with international trends, partly or totally foreign-owned firms outsource much more in global R&D spending sectors than do companies primarily in domestic ownership. Inward FDI and outsourcing R&D from abroad are now playing a major role in university research and are crucial in several fields. The internationalisation of universities' business research contract portfolio has speeded up the development of university-industry collaboration.

The fact that foreign business accounts for a relatively large proportion of the financial resources of universities may indicate that the S&T capabilities of Hungarian HE are suitable for foreign business. Contracts with industry have their effect on both the input and output sides.

Universities make up a relatively large proportion of partners in FDI-led R&D. That may be either a sign of the attractiveness of universities or of the limited availability of suitable domestic companies. A further alternative is that this symptomises an imbalance between publicly- and privately-funded researches since it is the case that private funds penetrate into sectors earlier occupied by public funds.

In the context of open innovation, business-funded university research is crucial, providing opportunities for universities to diversify their sources of funding and for society as a whole to become more innovative and competitive. However, an appropriate balance between public and private funding must be found, especially since companies are generally reducing their focus on basic and longer-term research in response to competition and shorter product cycles.

The present economic crisis inevitably has an effect on FDI-led R&D and innovation. In an environment where economic crises are so threatening, the strong sectoral concentration of outsourced R&D is dangerous. Although the presence of the automotive industry in the economy and in business-financed R&D was one of the country's strengths in the first part of the 21st century, it leaves Hungary's economy and business-funded university research fragile, as a narrow research portfolio is problematic.

The increasing worldwide competition among HE organisations creates a greater demand for detailed information on university collaboration, and it is vital to know the impact of collaborative (and contract) research on the university research agenda and performance, since a high level of FDI also creates risks that national resources may be diverted from the country's needs to meet the short-term objectives of foreign interests.

The scarcity of data and indicators were obstacles to a thorough analysis, and the indicators which permit a little analysis (at least testing ideas and metrics) were prepared from various databanks. Our statistical analysis showed that, to some extent, the internationalisation of business R&D in Hungary matches those global trends which are serving global open innovation. The so-called global R&D spending sectors have outsourced a much higher proportion of R&D to Hungary than have other sectors.

A very important question for the future of the triple helix model is whether collaboration for asset-exploitation can be transformed into

profit-driven partnerships, and a further issue is how local businesses can expand their development partnerships with global players and benefit from spillovers from global innovation and foreign investors.

Our analysis demonstrates the importance of this topic for Hungary and for similarly situated countries. Increasing competition for R&D-related foreign direct investment is making the catching-up process more difficult and more risky for Hungary as a small emerging economy. Yesterday's successes in attracting investors and collaborators give no guarantees for the future.

Our analysis also highlighted the importance for policy-makers to investigate further the linkages between production and the exploitation of new knowledge if these are separated in spatial terms by globally open innovation.

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KEY TERMS AND DEFINITIONS

Business Research and Development: Business R&D comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications The financier and/or performer of these activities are business organisations. (Frascati Manual, 2002 p. 30.)

Co-Publications: A co-publication is the result of co-operation between representatives of each entity and each country taking part in a particular joint research programme. Such research forges links between the parties (scientists, laboratories, institutions, countries, etc.) that have worked together to produce a scientific paper. (Okubo, 1997, p. 28.)

Global R&D Spending Sectors: In certain industries outsourced cross-border R&D is more characteristic than in others. The main R&D-spending multinational companies are concentrated on these few sectors. These include the IT, automotive and pharmaceutical industry, biotechnology, electronic, electrical and aerospace industries.

Indirect University Patents: The owner of patent is the inventor (faculty member) not the university as an institution itself or the patent is jointly-owned by faculty members and other individuals or organisations.

Open Innovation: Open innovation is a paradigm that assumes the firms can and should use external ideas as well as internal ideas, and

internal and external paths to market, as the firms look to advance their technology (Chesbrough, 2003, p. 24.)

Patent Inventor: Those individuals are inventors who attended in producing novelty that has industrial applicability. Country of residence of the inventor may differ from country of patent applicant/assignee.

Patents Owned: Patent is a legal title protecting an invention. The legal protection gives its owner the right to exclude others from making, using, selling the patented invention for the term of the patent. The applicants (or assignees in the US) will be the owners of the patent if it is granted. The owner may be the same person as inventor or employer company of inventor. But owner can be different from inventors and their respective organizations.

Third Mission of Higher Education: This means the university's relationship with the non-academic outside world: industry, public authorities and society. The 3rd mission includes several different activities such as the commercialization of academic knowledge through collaboration with industry, patenting/licensing, creation of spin-off companies, participation in policy-making, involvement in social and cultural life. (OEU Guide, 2006 p. 127.)

Transition Economies: The term *"transition economy"* is frequently used to refer to the countries of Central and Eastern Europe after the fall of the communist or socialist regimes in the end of the 1980's. Thereby, transition means the status of those countries during the evolution from a command economy to a market-based economy. This movement is usually characterised by the changing and creating of institutions, particularly private enterprises; changes in the role of the state, thereby, the creation of fundamentally different governmental institutions; and the promotion of private-owned enterprises, markets and independent financial institutions. (Falke, 2001 p. 1-2.)

ENDNOTES

1 "Open" does not mean "free" (as with some software); the payments of licence fees as well as other financial arrangements are a feature of open innovation.

2 "Open innovation" is broader than pure outsourcing, but this paper does not deal with other forms.

3 The concept of open innovation relates not only to the importance of knowledge-sourcing, but also to the exploitation of internal innovation together with external partners.

4 Instead of three "Missions", Laredo (2007) suggests that universities carry out three "Functions" which can be categorised as: (1) Mass Tertiary Education (leading to a Bachelor degree), (2) Professional Specialised Higher Education and Research (leading to a "professional" MA or MSc as the core degree, with "problem-solving research" as the core activity) and (3) "Academic Training and Research" (leading to a PhD as the core degree and involving publications as a core output). While the first and the third of these are clearly found already at local and international level, the second is focused on professions and follows their internationalisation.

5 The role of business in financing university R&D is studied in relation to issues such as the danger for the basic ethos of a university of how the choice of topic and the input of the university can contribute to the advancement of science. These important issues are beyond the scope of this chapter.

6 According to anecdotal evidence, the world economic crisis has affected corporate R&D less than production. The withdrawal of FDI, and closed factories have resulted in a reduction in FDI-led R&D, but, at the same time, we can observe strong innovation activity applied to try to break out of the economic

crisis.. Naturally, withdrawal and increasing FDI-led R&D investment occur in different companies and sectors.

[7] Both innovation and FDI policies focus on this issue. The emerging vision of the modern, innovative Hungarian economy, able to compete successfully in the global arena, produced policy which encourages companies to be innovation-oriented and universities to develop, beyond their traditional teaching mission, both their research performance and their capacity to transfer research results and new knowledge in order to convert these into commercially relevant innovations.

Despite many efforts to launch relevant programmes, the competence and attractiveness of universities for strategic research partnerships with the private sector has remained heterogeneous and somewhat unsatisfactory due to shortcomings in their knowledge base and their capability to act as high-performing research partners in collaborative projects.

[8] Outsourced R&D expenditure cannot be broken down further, and no information is available on the proportion of R&D outsourced to Higher Education.

[9] The automotive industry is a typical example of where the borderline between experimental and simple development is not very strong. If companies wish to avoid an innovation tax or benefit from an R&D tax credit system, they 'extend' experimental development, and so these figures must be interpreted with caution. Due to the R&D tax credit system there are always problems with figures relating to the automotive industry. Even if R&D expenditure and contracting-out figures were lower after revision, this sector actually invests significant amounts in R&D and outsourcing to universities.

[10] Lengyel and Leydesdorff (2007) observed that 'foreign-owned firms may have had determining roles on triple helix mechanisms in Hungary.' During the first and early second phase of the transition process 'the internal linkages were weakened and external linkages asynchronously reinforced. … Universities could further develop international relations … and FDI became a major factor in the transformation process.' (pp. 22-23)

[11] During the course of this exercise, the report form was modified several times and the availability of this source for research purpose changed. The new law on HE which guaranteed the autonomy of HE Institutions abolished this data collection on the R&D finance sources of HE Institutions. For our analysis, the disadvantage of this is that there are no figures after 2005 following Hungary's accession to the EU (in May 2004).

[12] The databank was prepared for the Verinekt project. Here we use only one part of it to discuss the relationship between foreign businesses and universities.

[13] Three graduate students, Gábor Csizmazia, Vilmos Klein and Szabolcs Szőke collected the names of the contractors from the report forms and classified them by sector (public and private) and by origin (domestic-owned, domiciled foreign-owned, foreign-located, EU and other international sources). Web searches were an important tool for classification.

[14] See the description of the sample in Inzelt et. al. 2009.

[15] In addition to the values of this indicator, its shortcomings are also well known.

[16] The patent documents list both inventors and applicants. The inventor is the person who invents something which did not exist before, but this novelty has to have industrial applicability to obtain a patent. The applicant is the holder of the legal rights and obligations of a patent application. Applicant may be the same individual as inventor or may be an organisation (company or university). If

the applicant is an organisation it can be the employer of an inventor or another organisation in the same or in different countries. Patent documents allow inventors and applicants to be identified by their country of origin, by the organisations of applicants and, in many cases, by the organisations of inventors. 'Through the applicant's and inventor's addresses it is possible to track the patterns and the intensity of international co-invention ... foreign ownership of domestic inventions and vice versa.' (OECD 2009, p. 32.)

17 If the research funding company is the sole owner of the patented university-related invention, the contracts between university/faculty members and company may regulate the role of the inventors in two different ways: include or exclude the name of the faculty members from the list of inventors in the patent application. The compensation of inventors is usually generous if they are excluded from the list of inventors. However, the university itself is usually not compensated. The patent statistics are not able to follow these 'indirect' university patents. (See the discussion on measurement in Inzelt et. al. 2006 pp. 139-147)

18 Data are not yet available on how the Law on Higher Education (2005) affects the processes.

19 According to the OECD definition (2009), the Triadic Patent Family is a set of patent applications filed at the European Patent Office (EPO), the Japan Patent Office (JPO), and granted by the US Patent and Trademark Office (USPTO), sharing one or more priority applications.

20 In the present stage of the databank, inventors are not identified as employees of universities. Presumably the general picture on the relationship between inventors and applicants does not differ from the relationship between universities and foreign applicants. The relevant sources and resources are missing pair-match the list of inventors with faculty members.

21 The locations of inventors and applicants were identified by the addresses, and so those with Hungarian addresses are listed as Hungarians. The Hungarian sample was selected by Zoltán Benke, graduate student, from the "Triadic Patent Families".

22 Following the period investigated, legislation changed. Under the new regulation (Law on Innovation 2004 and Law on Higher Education 2005) HE Institutions have to set up or strengthen their technology transfer organisations, re-regulate ownership and share licence income from patents between university and inventor. More transparent regulation and better management of intellectual property may make HE Institutions more attractive for business organisations and also may result in the better treatment of inventions.

23 In given cases the information was enough to link Hungarian inventors to universities as the inventors were well-known Hungarian scientists.