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Transnational Corporations as the Driving Forces Behind the World's Research and Development Activity in Terms of R&D Expenditure

Abstract

As discussed in the literature, more and more transnational corporations (TNCs) were attaching importance to research and development (R&D) activity from the 1970s through the 2000s. This growing involvement of TNCs in R&D resulted in their dominant role in global R&D expenditure. Indeed, a comparative analysis of financial data collected for the group of the 102 largest corporate R&D spenders worldwide in 2007 showed that this group of TNCs accounted for a significant share of the world's R&D expenditure not only in 2007 alone but also in the period of 2000–2011. Moreover, a similarity between their home countries and the countries being top R&D spenders was found; however, most of these corporations were conducting their R&D at international level. Furthermore, the analysed TNCs operated mostly in technology-intensive industries, for which the foundations were provided by a multidisciplinary science and technology basis.

Keywords: transnational corporation, research and development, R&D expenditure
JEL Codes: F23, O32

1. Introduction

The world has witnessed the fast-paced progress in science and technology (S&T) at the turn of the 20th and 21st centuries that was boosted mostly by the ongoing information revolution, which had started in the 1960 s. Thanks to advances in computer and information sciences, telecommunications and microelectronic engineering, as these laid the foundations for the above-mentioned revolution, research and development (R&D) processes were dramatically streamlined in terms of collecting, processing and transferring big amounts of data and information in the decades of the 1970 s through the 1990s. Thus, on the one hand, more and more innovation-oriented companies were becoming less risk averse, thereby undertaking R&D activity that always carry some level of risk of failure; on the other hand, lots of different forms of collaboration in S&T – involving companies, universities and other institutions – were continually developed.

As a result of these dynamic changes, the two megatrends in science and technology were set, and are still continued, i.e.[1]:

1. Convergence between different existing fields of science and technology, which has resulted in the emergence of new hybrid fields, e.g. biotechnology, nanotechnology.
2. Creation of completely new disciplines within existing fields of science and technology, e.g. genomics within genetics.

Transnational corporations (TNCs), especially large ones operating on a global scale, contributed to strengthening these megatrends due to their growing involvement in research and development from the 1970s through the 2000s, which resulted in their dominant role in global R&D expenditure.

The purpose of this paper is to provide some evidence for the above thesis by discussion of the results of an analysis of data on R&D expenditure of the world's top 102 corporate R&D spenders in 2007 with the emphasis on a reference period of 2000–2011.

[1] K. Poznańska, K.M. Kraj, *Badania i rozwój w korporacjach transnarodowych. Organizacja. Umiędzynarodowienie*, Wydawnictwo Naukowe PWN, Warsaw 2015, p. 8.

2. Internationalisation of Corporate R&D Activity as a Key Process Leading to TNCs' Dominance in the World's R&D Expenditure

There were two key stimuli for an increasing involvement of TNCs in research and development activity, and its international decentralisation, in the decades of the 1970s through the 2000s that resulted in their dominant role in global R&D expenditure.

Firstly, continuous improvement in information and communication technologies (ICT) helped companies significantly increase the pace of carrying out different phases of their R&D projects as well as improve coordination and secure confidentiality of R&D programmes involving geographically dispersed corporate units[2].

Secondly, more and more countries located in different regions of the world were undergoing the profound socio-economic and political transformation in those decades, which included some degree of deregulation of their domestic economies and openness to foreign direct investments as well as implementation of innovation policies. This trend created new investment and market opportunities for transnational corporations[3].

The above-mentioned processes also led to developing a knowledge-intensive globalising economy that started a new era of an increasingly competitive and turbulent environment for internationally– and globally-oriented companies[4]. Indeed, the greater importance needs to be attached to knowledge and innovations, especially technological ones, as a new primary basis for creating and strengthening the corporate sustainable competitive advantage[5]. D. Castellani and A. Zanfei best highlighted this crucial interdependence between the international expansion of a company and its capabilities to create and utilise innovations: *'on the one hand innovation is a key engine of internationalisation as it largely contributes to make it profitable to compete*

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[2] N. Kumar, *Multinational Enterprises, Overseas R&D Activity and the Global Technological Order*, Research and Information System, New Delhi 1999, pp. 13–14; P. Reddy, *Globalization of Corporate R&D: Implications for Innovation Systems in Host Countries*, Routledge, London–New York 2000, pp. 173–174.

[3] For example, see: J.H. Dunning, *Multinational Enterprises and the Global Economy*, Addison-Wesley, Workingham 1992; *Regions, Globalization, and the Knowledge-Based Economy*, ed. J.H. Dunning, Oxford University Press, Oxford–New York 2000; R. Gilpin, *The Challenge of Global Capitalism. The World Economy in the 21st Century*, Princeton University Press, Princeton 2000.

[4] See in particular discussion by Y. Doz, J. Santos, P. Williamson in their book: *From Global to Metanational: How Companies Win in the Knowledge Economy*, Harvard Business School Press, Boston MA 2001, pp. 42–46.

[5] K.M. Kraj, *Corporate R&D Centres in Poland*, in: *Przedsiębiorstwo wobec wyzwań globalnych*, eds. A. Herman, K. Poznańska, vol. 2, SGH, Warsaw 2008, p. 171.

in foreign markets. On the other hand, internationalisation creates important innovation opportunities. In this context, multinationals play a key role in the international exploitation and generation of innovative advantages[6].

As a result of this increasing interdependence, the decades of the 1970s through the 2000s were marked not only by a growing number of transnational corporations investing heavily in R&D but also by the intensifying internationalisation of this corporate activity in more and more TNCs establishing foreign R&D units in selected host countries[7]. Indeed, the involvement of transnational corporations in research and development activity, especially on an international scale, was increasing with every next decade since the 1970s, thereby attracting more and more attention from academic researchers, governmental agencies and international organisations[8].

To better depict the significance of internationalisation of corporate research and development in the last four decades, as it led to a dominant role of R&D-active TNCs in global R&D expenditure, a brief literature review is made below.

The centralisation of industrial R&D in home countries of TNCs, which was typical of the postwar period of the late 1940s through the 1960s, was also a popular approach among R&D-active TNCs in the 1970s since the focus was on building up sales and manufacturing operations performed abroad[9]. However, in the late 1970s and the early 1980s, not only American corporations but also Western European, Japanese and Canadian corporations started to locate some of their R&D operations in selected host countries (both developed and fast-developing ones) either by setting up R&D units or by acquiring such local units along with plants and other assets. It was aimed at supporting foreign subsidiaries with complementary design and development capabilities[10]. Although the primary role of foreign corporate R&D units

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[6] D. Castellani, A. Zanfei, *Multinational Firms, Innovation and Productivity,* Edward Elgar Publishing, Cheltenham–Northampton 2006, p. 9.

[7] It should be, however, emphasised that internationalisation of corporate R&D did start in the interwar period since a few large European and American corporations, which were operating in the chemical and electrical equipment industries, established some R&D units abroad (see J. Niosi, *The Globalization of Canada's R&D*, "Management International Review" 1997, vol. 37(4), p. 388; P. Reddy, *Globalization of...*, op. cit., p. 1).

[8] For example, see: J.N. Behrman, W.A. Fischer, *Overseas R&D Activities of Transnational Companies,* Oelgeschlager, Gunn & Hain, Cambridge, MA 1980; *Technical Change and the World Economy: Convergence and Divergence in Technology Strategies*, ed. J. Hagedoorn, Edward Elgar Publishing, Cheltenham–Northampton 1995; R. Boutellier, O. Gassmann, M. von Zedtwitz, *Managing Global Innovation. Uncovering the Secrets of Future Competitiveness*, Springer-Verlag, second revised edition, Berlin–Heidelberg 2000; *World Investment Report 2005: Transnational Corporations and the Internationalization of R&D,* UNCTAD, New York–Geneva 2005.

[9] A. Gerybadze, G. Reger, *Globalization of R&D: Recent Changes in the Management of Innovation in Transnational Corporations*, "Research Policy" 1999, vol. 28, iss. 2–3 (Special Issue), p. 254.

[10] J. Niosi, *The Globalization of...*, op. cit., p. 388; A. Gerybadze, G. Reger, *Globalization of...*, op. cit., p. 254.

was transfer and local adaptation of product/process technologies developed by their parent corporation's central R&D labs, some of these units were set up to be involved mostly in research or development projects of high priority, e.g. development of new flagship products or new technologies[11]. It is worth mentioning that governments in developing countries sought to attract foreign corporate R&D units since it was a vital part of their industrialisation policy[12].

In other words, different research showed that at the turn of the 1970s and the 1980s transnational corporations started to play a crucial role in boosting research and development activity undertaken in different countries. Yet there were no studies aimed at estimating the total R&D expenditure incurred by the then leading corporate R&D spenders worldwide.

From the mid-1980s through the 1990s, as studies showed, internationalisation of corporate R&D was intensifying in terms of its pace, the scope of R&D operations performed abroad and the geographical spread. Researchers found evidence of this strong trend towards the international decentralisation of corporate R&D by analysing either patent activity of TNCs or geographical distribution of their R&D spending. According to their findings, more and more transnational corporations originating in North America, Western Europe and Japan were building up their corporate networks of R&D units at international level, and increasing their R&D expenditure. However, depending on home country, TNCs differed widely in the degree of internationalisation of their R&D facilities. It was Europe-based TNCs operating in technology-intensive industries that took the lead in this process followed by the US-based TNCs while Japan-based TNCs were still conducting most of their R&D in their home country[13].

It is worth mentioning that the growing involvement of TNCs in research and development at the turn of the 1980s and the 1990s was reflected, to some degree, in the first international R&D scoreboard providing financial data on the largest R&D-active companies in 1990, which was prepared under the auspices of the British

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[11] See in particular a study by R. Ronstadt, *Research and Development Abroad by U.S. Multinationals*, Praeger Publishers, New York 1977.

[12] P. Reddy, *Globalization of...*, op. cit., p. 52.

[13] Ch. Freeman, J. Hagedoorn, *Convergence and Divergence in the Internationalization of Technology*, in: *Technical Change and the World Economy...*, op. cit., pp. 49–51; N. Kumar, *Multinational Enterprises...*, op. cit., pp. 8–9; O. Gassmann, M. von Zedtwitz, *New Concepts and Trends in International R&D Organization*, "Research Policy" 1999, vol. 28, iss. 2–3 (Special Issue), pp. 231–232; P. Patel, M. Vega, *Patterns of Internationalisation of Corporate Technology: Location vs Home Country Advantages*, "Research Policy" 1999, vol. 28, iss. 2–3 (Special Issue), pp. 147–151; M. Hemmert, *International Organization of R&D and Technology Acquisition Performance of High-Tech Business Units*, "Management International Review" 2003, vol. 43(4), p. 362.

government. According to this scoreboard, the composition of the top 100 corporate R&D spenders in 1990 by home country and by industry was as follows[14]:

a) all the identified top companies were based in the United States, in two Western European countries (i.e. the United Kingdom and Germany) and Japan;
b) their total R&D spending was estimated at $132.14 billion[15], of which 40.5%, 29.4%, 21.5% and 8.6% was assigned to American, Japanese, German and British TNCs respectively;
c) the leading industries, which had the lion's share of this corporate R&D spending, were technology-intensive ones, i.e. automotive, chemicals, electrical & electronics, health care, IT and telecommunications, aerospace.

Another significant change that occurred in the nature of internationalisation of corporate R&D in the 1990s, especially in the second half of that decade, was higher differentiation of foreign corporate R&D units by role, which was observed among many TNCs operating in different technology-intensive industries. For example, corporate R&D centres of excellence were established in such host countries that were offering unique R&D resources in order to carry out research and development projects of high priority to their parent corporations[16]. Moreover, TNCs sought to reorganise and manage their corporate networks of internationally dispersed R&D units in a truly integrated way with the aim of achieving an acceptable cost-efficiency ratio due to higher volatility of the global competitive environment[17]. Thus the driving forces for locating corporate R&D units in selected host countries, both developed and fast-developing ones, were enriched by new motivations such as access to specialised research networks, demand for talented scientists and engineers in an increasing number of emerging and converging fields of science and technology, and

[14] *The 1991 R&D Scoreboard*, http://webarchive.nationalarchives.gov.uk/20101208170217/http://www. innovation.gov.uk/rd_scoreboard/?p=31 (8.04.2017). This R&D scoreboard series was aimed at analysing financial data of the top UK-based and non-UK-based companies, most of which were transnational corporations, by their R&D expenditure. The scoreboard was prepared and released annually from 1991 through 2010 under the auspices of the British government departments.

[15] In this paper, the sign '$' refers to the U.S. dollar. It must be emphasised that all the figures in the above R&D scoreboard series were presented in the British pound. Thus all the original estimates referred to in this paper were translated into the U.S. dollar by the paper's author (at the exchange rate ruling at 31 December of an analysed year to be in accordance with the foreign currency translation principle adopted in this series).

[16] W. Kuemmerle, *Building Effective R&D Capabilities Abroad*, "Harvard Business Review" 1997, March–April; J.W. Medcof, *A Taxonomy of Internationally Dispersed Technology Units and Its Application to Management Issues*, "R&D Management" 1997, October, vol. 27, iss. 4.

[17] See in particular: A. Gerybadze, G. Reger, *Globalization of...*, op. cit.; O. Gassmann, M. von Zedtwitz, *New Concepts and...*, op. cit.

the need to optimise the total cost of corporate R&D projects undertaken[18]. This changing nature of major motivations behind internationalisation of corporate R&D was highlighted by researchers. For example, R.D. Pearce pointed out that the foreign corporate R&D activities had moved *'from tactical short-term adaptation operations to more strategic medium-term product development and longer-term knowledge creation'*[19]. Likewise, A. Gerybadze and G. Reger referred to the changing nature of this process by emphasising that: *'This change has resulted in a new paradigm of transnational innovation (...) the new paradigm of transnational innovation is characterized by: intense market and technology interaction, multiple centers of knowledge (at several geographical locations), cross-functional learning (...), a combination of inward and outward learning (...), reverse and interactive technology transfer (...)'*[20].

Despite the changing pattern of major motivations behind internationalisation of corporate R&D, especially a quest to optimise the R&D cost-efficiency ratio, the leading R&D-active TNCs kept incurring significant expenditure on research and development. It is worth mentioning that:

1) O. Gassmann and M. von Zedtwitz estimated – based on data from OECD and companies – that the 50 largest corporate R&D spenders worldwide accounted for a considerable share of the total R&D expenditure in the Triad nations in the mid-1990 s, i.e. 33% in the United States, 42% in Western Europe and 57% in Japan[21].
2) According to *the 2000 R&D Scoreboard* by one of the British government departments, the group of the 300 largest corporate R&D spenders worldwide incurred the R&D expenditure estimated at $252.82 billion for the year 1999[22]. It is worth adding that most of these corporations were based in the USA, Western European countries and Japan, and were operating in different manufacturing and service industries, technology-intensive ones in particular (IT, automotive, pharmaceuticals, electronic & electrical, chemicals)[23].

Thus at the turn of the 20th and 21st century transnational corporations played a crucial role in boosting progress in science and technology as they had already linked, through their networks of corporate R&D units, different countries and

[18] K.M. Kraj, *Corporate R&D Centres...*, op. cit., pp. 175–176; see also E.B. Roberts, *Benchmarking Global Strategic Management of Technology*, "Research Technology Management" 2001, March–April, vol. 44, no. 2.

[19] R.D. Pearce, *Decentralised R&D and Strategic Competitiveness: Globalised Approaches to Generation and Use of Technology in Multinational Enterprises (MNEs)*, "Research Policy" 1999, vol. 28, iss. 2–3 (Special Issue), p. 158.

[20] A. Gerybadze, G. Reger, *Globalization of...*, op. cit., pp. 254–255.

[21] O. Gassmann, M. von Zedtwitz, *New Concepts and...*, op. cit., p. 232.

[22] *The 2000 R&D Scoreboard*, http://webarchive.nationalarchives.gov.uk/20101208170217/http://www. innovation.gov.uk/rd_scoreboard/?p=31 (8.04.2017).

[23] Ibidem.

their unique R&D resources to generate and apply new knowledge in diverse fields of S&T more efficiently.

The above-discussed trend in internationalisation of corporate R&D continued in the 2000 s, and was even intensified by new entrants, i.e. transnational corporations originating in the largest developing countries such as the mainland China[24] and India[25]. As a result of this trend among R&D-active TNCs, more and more studies were made to examine the impact of internationalisation of corporate R&D on countries involved in this process since such TNCs were bringing both potential benefits and costs, thereby affecting such countries' innovation policy[26]. Moreover, the significant role of TNCs in the world's research and development activity, especially in terms of R&D expenditure, attracted constant attention from both business analysts and international organisations. It is therefore worth mentioning that:

a) in the year 2004 a new R&D scoreboard series, i.e. *the EU Industrial R&D Investment Scoreboard*, was initiated by the European Commission with the aim of analysing economic and financial data of the top EU-based and non-EU-based corporate R&D spenders, most of which have been transnational corporations[27];
b) in the year 2005 Booz & Company[28], a global strategy consulting firm, initiated *the Global Innovation 1000* study with the aim of investigating the relationship between the world's top 1000 corporations' R&D expenses and their performance, especially in the context of innovative activity[29].

Both the previously referred to corporate R&D scoreboard series by the British government departments and the above studies showed that[30]:

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[24] The term 'mainland China' refers to the geographical area of the People's Republic of China (PRC) without two so-called 'special administrative regions' (SARs, i.e. Hong Kong and Macau).

[25] See in particular: *Globalization of R&D and Developing Countries*, Proceedings of the Expert Meeting. Geneva 24–26 January 2005, UNCTAD, New York–Geneva 2005.

[26] See in particular: *World Investment Report 2005...*, op. cit.; *The Internationalisation of Business R&D. Evidence, Impacts and Implications*, OECD, Paris 2008.

[27] The *EU Industrial R&D Investment Scoreboard* series has been prepared and released annually under the auspices of the European Commission since 2004. All the editions are available to download from the following website: http://iri.jrc.ec.europa.eu/scoreboard.html). In general, the adopted methodology is similar to that of the previously referred to 'British' R&D scoreboard series; the major difference is euro as the presentation currency.

[28] Since 2014 the company has been operating under the name "Strategy&" as a wholly-owned subsidiary of PwC, a global consulting firm; more information about this study is available on the following website: https://www.strategyand.pwc.com/global/home/what-we-think/51025132/past-year-studies (18.04.2017).

[29] Ibidem.

[30] Compare in particular: *The 2004 R&D Scoreboard*, UK DTI, and *The 2010 R&D Scoreboard*, UK BIS, http://webarchive.nationalarchives.gov.uk/20101208170217/http://www.innovation.gov.uk/rd_scoreboard/?p=31 (8.04.2017); *The 2004 EU Industrial R&D Investment Scoreboard*, European Commission, DG-JRC/DG-RTD, and *The 2010 EU Industrial R&D Investment Scoreboard*, European Commission, JRC/

1) There were more and more R&D-active TNCs that as a whole tended to increase their R&D expenditure throughout the 2000 s, except for the year 2009 which proved to have a negative impact on corporate R&D budgets, thereby resulting in a slight decrease in R&D expenditure incurred by the leading TNCs (between 1.6% and 3.5%, depending on the study)[31].
2) There was high concentration of corporate R&D spending by industry throughout the 2000 s since the leading industries, which accounted for the largest share of corporate R&D expenditure, were the following technology-intensive industries: IT, automotive, pharmaceuticals & biotechnology, electronic & electrical, chemicals, aerospace & defense[32].
3) The breakdown of the world's top corporate R&D spenders by home country remained quite stable over the 2000 s since it was still TNCs based in the United States, Japan and Europe that constituted the predominant group among the largest corporate R&D spenders.

To sum up, the above three studies provided a general perspective on corporate R&D activity in the 2000 s, especially in terms of R&D expenditure, thereby representing a valuable contribution to the discussion of the role of TNCs in the world's research and development activity. However, the 2000 s were marked by economic fluctuations in the world economy that resulted in the three following subperiods[33]:

DG-RTD http://iri.jrc.ec.europa.eu/scoreboard.html (18.04.2017); B. Jaruzelski, K. Dehoff, R. Bordia, *The 2005 Global Innovation 1000 Study: Money isn't everything*, Booz & Co., "strategy+business" 2005, Winter, iss. 41, and B. Jaruzelski, K. Dehoff, *The 2010 Global Innovation 1000 Study: How the Top Innovators Keep Winning*, Booz & Co., "strategy+business" 2010, Winter, iss. 61, https://www.strategyand.pwc.com/global/home/ what-we-think/51025132/past-year-studies (18.04.2017).

[31] For example, the number of the largest corporate R&D spenders worldwide, which were listed in the two 'British' R&D scoreboard editions referred to, increased from 700 (the 2004 edition) to 1000 (the 2010 edition), and their total R&D expenditure was estimated at $ 366.3 billion and $ 555.52 billion respectively. The second estimate is comparable to that reported in *the 2010 Global Innovation 1000 Study* by Booz & Co. analysts, according to whom the identified group of the world's top 1000 corporate R&D spenders incurred R&D expenses of $ 503 billion in 2009. The difference between both estimates may be attributable to some differences in the methodology adopted in these studies (e.g. the different foreign currency translation principles) that affected the composition of companies included in each of these yearly rankings.

[32] According to the 2004 editions of the 'British' and the 'EU' R&D scoreboards, in which the world's top 700 and 685 R&D-active companies were listed respectively, the above-listed industries accounted for 82.2% of the total R&D expenditure of these groups of companies in 2003. According to the 2010 editions of the above scoreboard series, the corresponding ratio for the year 2009 was lower, yet still relatively high, i.e. 74.6% and 70.3% (this second percentage didn't include 'aerospace & defense') in the 'British' and the 'EU' R&D scoreboards respectively; it should be, however, emphasised that the number of the world's top R&D-active companies listed in these 2010 editions was 1000 and 1400 respectively, thereby including a broader scope of industries.

[33] K. Poznańska, K.M. Kraj, *Badania i rozwój...*, op. cit., pp. 64–65.

a) the subperiod of 2000 through 2003: a downturn in the world economy in the aftermath of a burst of 'the Internet bubble' in March 2000 in the USA[34];
b) the subperiod of 2004 through 2007: an upturn in the world economy – according to the World Bank, the vast majority of countries achieved economic growth[35];
c) the subperiod of 2008 through 2009: another downturn in the world economy in the aftermath of a global financial crisis, which also continued at the beginning of the 2010 s, i.e. in 2010 and 2011.

Thus, given these economic fluctuations that occurred last decade, in the outlined context of internationalisation of corporate R&D two key research questions arise:

1. To what extent were the largest corporate R&D spenders worldwide playing a crucial role in global R&D expenditure in the period of 2000 through 2011?
2. Did the last decade's economic turbulence affect the leading corporations' R&D spending throughout the 2000s?

In order to give an answer to these questions, a comparative analysis of data on R&D expenditure of the world's top 102 corporate R&D spenders in 2007, with the emphasis on a reference period of 2000–2011, was carried out against a background of countries' R&D expenditure aggregated at global level.

3. Research Methodology and Selected Firms

The initial aim of the research discussed in this paper was to determine how many transnational corporations invested heavily in R&D, i.e. no less than $100 million in 2007, which proved to be the last year of an upturn in the world economy in the 2000 s. Selection of R&D-active TNCs that released data on their R&D expenditure for the year 2007 was made at the preliminary stage of research. Corporations which were consolidated (as being subsidiaries) by other corporations (as being parent companies) already included in the selected group – were excluded in order to avoid double-counting. As a result of this preliminary research, some 800 TNCs were the subject of further research, which was a three-stage analysis, i.e.:

1. For each of the selected companies, R&D expenditure calculations were made for the year 2007 in order to determine the exact number of TNCs that met the

[34] A rapid decline in the market capitalisation of Internet-oriented, technology-intensive companies (so-called 'dotcoms') on the Nasdaq stock exchange that first resulted in an economic recession in the USA, and later in an economic recession or slowdown in other developed countries as well as in some developing ones.

[35] According to the World Bank's data (referred to in Section 2 of this paper), it was 94–95% of the monitored countries, depending on the year under consideration.

above-mentioned financial criterion. This stage resulted in selection of 618 TNCs (referred further to as 'TNC-618').

2. For each of the companies included in TNC-618, R&D expenditure calculations were also made for the years 2000–2006. This stage, however, revealed the lack of available data on corporate R&D spending for a considerable percentage of TNCs for some years within the above period, especially 2000 through 2003.
3. The last stage was a broadened analysis of a subgroup of TNCs selected from the group TNC-618, i.e. the focus was on corporations with R&D expenditure above $ 1 billion incurred in the year 2007. It resulted in selection of 102 TNCs (referred further to as 'TNC-102')[36], for which R&D expenditure calculations were also made for the years 2008–2011.

Data on corporate R&D spending were collected from annual consolidated financial statements of TNCs[37]. However, in the case of companies whose fiscal year was a twelve-month period different from a calendar year, additional data were collected from either half-yearly or quarterly consolidated financial statements in order to make annualised estimates of their R&D expenditure. Moreover, in the case of companies that underwent merger, acquisition or demerger processes in the analysed period, estimates were made on the basis of data collected from consolidated financial statements of their corporate legal predecessors or legal successors to provide comparability of calculations on a year-on-year basis.

All the R&D expenditure figures, if not presented in the U.S. dollar, were translated into this currency at the yearly average exchange rates. The official exchange rates were derived from International Monetary Fund, International Financial Statistics through the website of the "World Development Indicators" database administered by the World Bank[38].

From the methodological point of view, this research differed from the two R&D scoreboard series referred to in Section 1 of this paper (i.e. the 'British' *R&D Scoreboard* series and the *EU Industrial R&D Investment Scoreboard* series) in that:

1. It was aimed at obtaining estimates of corporations' R&D expenditure incurred in the analysed calendar years, not fiscal years since some TNCs (especially

[36] It should be, however, emphasised that two TNCs (i.e. Porsche and Nortel Networks) were excluded from this subgroup, despite meeting the above financial criterion, as they were among those mentioned earlier in the context of lack of data on their R&D spending for some years within the period of 2000–2003.

[37] Any R&D subsidies, grants etc. received from governments or other institutions (e.g. collaborative partners) were excluded if such financial figures were disclosed separately.

[38] The website is available under the following address: http://data.worldbank.org/data-catalog/world-development-indicators. However, in the case of the exchange rate of the Taiwanese dollar to the U.S. dollar, the yearly average exchange rates were derived from a website of the currency converter provided by Oanda Corp., a global currency broker.

North American and Japanese ones) adopted a twelve-month period different from a calendar year as their fiscal year.

2. The yearly average exchange rates, not the end-year exchange rates were used to make currency translations since most TNCs reported their R&D expenditure as current expenses translated at the yearly average exchange rates while preparing their consolidated financial statements.

Both the above-described preliminary and further research was conducted by the author of this paper from 2009 through 2013. The major findings of this research as well as its methodology were first discussed in Polish in a book by K. Poznańska and K.M. Kraj[39].

To compare the obtained estimates of corporate R&D expenditure against that of the world, data on countries' R&D expenditure (i.e. GERD: gross domestic expenditure on R&D) reported in current local currency (at current prices) were derived from the "Science, Technology and Innovation" database developed and administered by the UNESCO Institute for Statistics (UIS)[40], and translated into the U.S. dollar on the above-mentioned principle. Two sets of data, i.e. 'June 2013 release' and 'July 2014 release', were used to make estimates of annual R&D expenditure for 36%–44% of the countries and territories included in the UN statistics (depending on availability of data for a particular year) and then aggregate the estimates at regional and global levels. Moreover, some macroeconomic data for the world and for countries were derived from the previously mentioned "World Development Indicators" database of the World Bank in July 2014.

4. A Dominant Role of Transnational Corporations in Global R&D Expenditure in the Period of 2000–2011

According to the calculations made on the basis of GERD data available, the world's R&D expenditure was continually increasing from 2000 through 2008, and then again from 2010 through 2011. Thus this trend was interrupted in 2009, which was marked by a severe economic downturn in the world economy[41], thereby resulting in a two percent decline in global R&D expenditure as compared to 2008. It is worth

[39] K. Poznańska, K.M. Kraj, *Badania i rozwój...*, op. cit., pp. 88–108 (chapter 3) and pp. 247–255 (appendixes 3 and 4).

[40] The website is available under the following address: http://data.uis.unesco.org/

[41] According to the World Bank's WDI database (July 2014 update), the 2009 GDP growth rates (at market prices based on constant local currency) were positive in 98 countries and negative in 95 countries.

mentioning that 2007 was the first year in which the world as a whole spent above $1 trillion on research and development (Table 1).

Moreover, the estimates suggest that there was quite a high correlation between the world's aggregate GDP changes and its R&D expenditure changes from 2000 through 2011 since the world's R&D intensity fluctuations were low – the ratio ranged between 1.86% and 1.98%, with an average of 1.92% for the above period. It should be, however, emphasised that this stable trend in global R&D expenditure was determined by the top ten leading countries in the world in terms of GERD – their share in annual global R&D expenditure fluctuated between 81% and 89% in the discussed period.

Thus it supports the findings of the studies referred to in Section 1 that there was a high geographical concentration of R&D activity in a relatively small group of countries in the period of 2000–2011, mostly in the Triad countries and a few fast-developing large countries, which were also found by researchers to be the countries most involved in internationalisation of corporate R&D activity (Table 2).

As illustrated in Table 2, the leading positions were held mostly by the same countries from 2000 through 2011, both at global and regional levels. The United States and Japan were the largest and the second-largest R&D spenders among countries respectively as well as the largest R&D spenders in their respective geographical regions. What is also worth commenting is the mainland China's impressive climb from the ninth position in 2000 to the third position in 2011 among the world's ten largest R&D spenders. It reflects this country's efforts to catch up with the Triad countries in terms of research and development capabilities and innovation performance.

Table 1. The estimates of annual global R&D expenditure in the period of 2000–2011 (the selected years)

	2000	2002	2004	2007	2009	2011
The world's R&D expenditure ($bn):	649.48	655.09	823.41	1 053.06	1 158.81	1 352.86
The number of countries and territories whose GERD is included in a relevant aggregate R&D expenditure:						
	78[A,B]	*94*[B]	*94*[B]	*94*[B]	*89*[B]	*82*[B,C]
The world's aggregate GDP ($bn):	32 981.13	34 000.45	42 938.44	56 694.80	58 884.50	71 448.81
The world's R&D intensity	1.97%	1.93%	1.92%	1.86%	1.97%	1.89%

Source: estimates based on the UIS 'Science, Technology & Innovation' database ('June 2013 release' and 'July 2014 release') and the World Bank's WDI database (July 2014 update); notes: A – a relevant annual global R&D expenditure is completed with GERD for the year 1999 with reference to Denmark, Sweden and Norway (data on their GERD for the year 2000 were not available); B – Owing to the fact that Australia and New Zealand were reporting their GERD every two years, i.e. Australia for even years and New Zealand for odd years, the estimates were completed with values of their GERD for the previous years, i.e. in the case of Australia – GERD for the years 2006, 2008 and 2010 is assigned to the years 2007, 2009 and 2011 respectively, in the case of New Zealand – GERD for the years 1999, 2001 and 2003 is assigned to the years 2000, 2002 and 2004 respectively; C – a relevant annual global R&D expenditure is completed: a) with GERD for the year 2009 with reference to Saudi Arabia and Thailand, b) with GERD for the year 2010 with reference to Chile, Hong Kong (China's SAR) and South Africa.

If this trend has been continued since then, the mainland China would strengthen its position as one of the two most important R&D spenders in the world by the end of this decade, thereby climbing to the position held by Japan for many years.

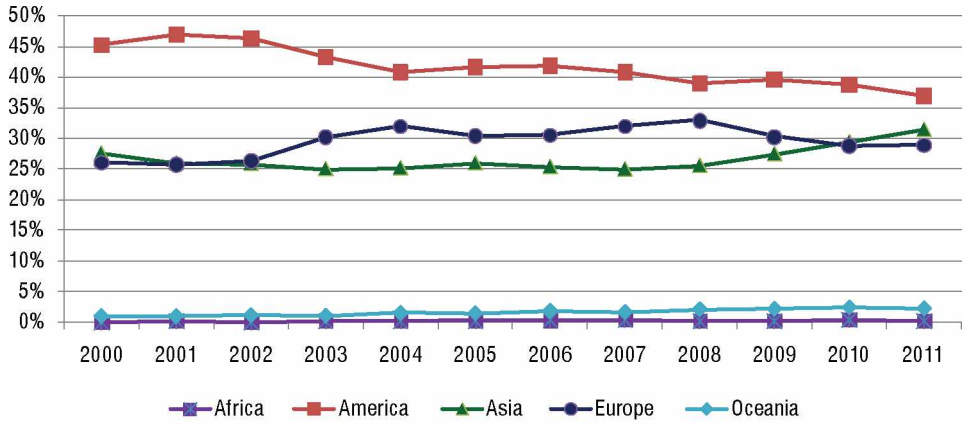
Table 2. The top leading countries in terms of GERD in the period of 2000–2011 from the global and regional perspectives (the selected years)

2000	2004	2007	2011
The top ten leading countries in the world [GERD, $bn]:			
1. United States [269.51] 2. Japan [142.02] 3. Germany [46.64] 4. France [28,52] 5. United Kingdom [26.81] 6. Canada [13.84] 7. South Korea [12.24] 8. Italy [11.48] 9. China[B] [10.82] 10. Sweden [9.27][1999]	1. United States [305.64] 2. Japan [145.88] 3. Germany [68.25] 4. France [44.32] 5. United Kingdom [37.07] 6. China[B] [23.76] 7. Canada [20.51] 8. South Korea [19.37] 9. Italy [18.94] 10. Sweden [12.94]	1. United States [380.32] 2. Japan [150.79] 3. Germany [84.15] 4. France [53.79] 5. United Kingdom [50.02] 6. China[B] [48.77] 7. South Korea [33.68] 8. Canada [27.96] 9. Italy [24.95] 10. Spain [18.26]	1. United States [429.14] 2. Japan [199.80] 3. China[B] [134.44] 4. Germany [104.96] 5. France [62.59] 6. South Korea [45.02] 7. United Kingdom [43.87] 8. Canada [31.02] 9. Brazil [29.96] 10. Australia [28.28][2010]
America: the regional leaders:[A]			
1. United States 2. Canada 3. Brazil [6.56] 4. Mexico [2.17]	1. United States 2. Canada 3. Brazil [5.97] 4. Mexico [3.04]	1. United States 2. Canada 3. Brazil [14.97] 4. Mexico [3.84]	1. United States 2. Canada 3. Brazil 4. Mexico [4.98]
Europe: the regional leaders:[A]			
1. Germany 2. France 3. United Kingdom 4. Italy	1. Germany 2. France 3. United Kingdom 4. Italy	1. Germany 2. France 3. United Kingdom 4. Italy	1. Germany 2. France 3. United Kingdom 4. Italy [27.54]
Asia: the regional leaders:[A]			
1. Japan 2. South Korea 3. China[B] 4. Israel [5.21]	1. Japan 2. China[B] 3. South Korea 4. India [5.32]	1. Japan 2. China[B] 3. South Korea 4. India [9.54]	1. Japan 2. China[B] 3. South Korea 4. India [15.56]
Oceania: the regional leaders:[A]			
1. Australia [6.04] 2. New Zealand [0.57][1999]	1. Australia [11.74] 2. New Zealand [0.96][2003]	1. Australia [16.39] [2006] 2. New Zealand [1.59]	1. Australia[2010] 2. New Zealand [2.07]
Africa: the regional leaders:[A]			
No data available	1. South Africa [1.86] 2. Morocco [0.33][2003] 3. Tunisia [0.28]	1. South Africa [2.64] 2. Morocco [0.42][2006] 3. Tunisia [0.39]	1. South Africa [2.77][2010] 2. Egypt [0.99]

Source: estimates based on the UIS 'Science, Technology & Innovation' database ('June 2013 release' and 'July 2014 release') and the World Bank's WDI database (July 2014 update); notes: A – GERD ($bn) presented for those regional leaders that are not counted among the world's top ten leading countries for a relevant year; B – GERD for the People's Republic of China, excluding estimates for two SARs (i.e. Hong Kong and Macau); see also the corresponding ranking of top countries for the year 2010: K. Poznańska, K.M. Kraj, *Badania i rozwój...*, op. cit., p. 68.

The regional breakdown of the leading countries in terms of R&D expenditure indicates that there were three crucial geographical regions, in which most of the world's R&D activity was conducted in the period of 2000–2011, i.e. America (with key roles played by the United States, Canada and Brazil), Europe (with key roles played by Germany, France, the United Kingdom and Italy) and Asia (with key roles played by Japan, South Korea and the mainland China). Figure 1 depicts the changes in the percentage share of the five major geographical regions in the world's R&D expenditure from 2000 through 2011.

Figure 1. The percentage share of the five major geographical regions in annual global R&D expenditure in the period of 2000–2011



Source: estimates based on the UIS 'Science, Technology & Innovation' database ('June 2013 release' and 'July 2014 release') and the World Bank's WDI database (July 2014 update).

As illustrated in Figure 1, although America and Europe played crucial roles in global R&D activity in the discussed period, their share was fluctuating. Moreover, it appears that at the end of the 2000 s both regions started the long-term downward trend in their importance in this activity in favour of Asia. Indeed, the share of America, Europe and Asia in global R&D expenditure was 45.2%, 26.1% and 27.6% respectively in 2000, and 37%, 29% and 31.5% respectively in 2011. It may herald a forthcoming new era in the global S&T progress, in which the largest R&D spenders from Asia will likely be playing a key role.

The distribution of the major region's shares in the world's R&D expenditure, including the leading countries in terms of GERD, corresponds to some degree with a breakdown of the world's top corporate R&D spenders in 2007 by home country. According to the author's research on corporate R&D spending, there were 618 transnational corporations (TNC-618) worldwide that invested $100 million

or more in research and development in 2007. With $474.62 billion spent on R&D, TNC-618 accounted for 45.1% of the world's R&D expenditure in a relevant year. Moreover, the lion's share of the total R&D expenditure of TNC-618 was incurred by two thirds of the group, i.e. 406 transnational corporations that originated in just three of the leading countries in global R&D activity, i.e. the United States, Japan and Germany (230, 124 and 52 companies respectively). Their aggregated R&D expenditure was estimated at $327.59 billion (i.e. 69% of the total R&D spending of TNC-618 in 2007). It is worth adding that Europe-based TNCs as a whole were second only to the US-based TNCs both in terms of the number of companies and the share of the total R&D expenditure of TNC-618 (197 companies with $164.66 billion spent on R&D against the group of 230 US-based companies with R&D expenditure of $185.8 billion). These findings go in line with the results of the previously discussed R&D scoreboard series.

Despite the fact that the mainland China's expenditure on R&D increased significantly between 2000 and 2011, there was only one transnational corporation originated and based in this country, which was counted among the leading corporate R&D spenders in 2007 within TNC-618[42]. However, the mainland China's progress reflects the findings of different research on internationalisation of corporate R&D that this country became one of the key host countries, especially in Asia, for many transnational corporations performing some of their R&D operations abroad[43], which resulted in such corporate activity being included in the country's R&D expenditure.

To better highlight a key role of TNCs in the world's R&D activity in the 2000s, closer attention was paid to the most important subgroup of TNC-618 in terms of R&D expenditure, i.e. the world's top corporate R&D spenders in 2007 that incurred R&D expenditure above $1 billion that year. It was the group of 102 transnational corporations (TNC-102), for which data were analysed with reference to the period of 2000–2011. Table 3 gives an overview of corporations included in TNC-102 by industry and home country.

[42] ZTE Corporation, a global company operating in the IT and telecommunications industries. According to the corporate information available, ZTE had already internationalised its R&D operations by the year 2007 by setting up some R&D centers in selected host countries in North America, Europe and Asia.

[43] For example, see: G.J. Tellis, A.B. Eisingerich, R.K. Chandy, J.C. Prabhu, *Competing for the Future: Patterns in the Global Location of R&D Centers by the World's Largest Firms*, Working Paper, Centre for India & Global Business, University of Cambridge – Judge Business School, 2009, www.india.jbs.cam.ac.uk/research/facultyresearch.html (24.03.2009).

Table 3. A breakdown of the world's top 102 corporate R&D spenders in 2007 by industry and home country

Industry	Number of TNCs by home country
IT and telecommunications	**25 TNCs** *of which:* US: 16 (*Microsoft, Intel, IBM, Cisco Systems, Motorola, Hewlett-Packard, Oracle, Google, Sun Microsystems, Qualcomm, AMD, EMC, Freescale Semiconductor, Broadcom, Yahoo!, Electronic Arts*), Japan: 2 (*NTT, Fujitsu*), Finland (*Nokia*), Sweden (*Ericsson*), UK (*BT*), Germany (*SAP*), France (*France Telecom*), Australia (*Telstra*), France/US* (*Alcatel-Lucent*)
Health care and pharmaceuticals	**24 TNCs** *of which:* US: 10 (*Pfizer, Merck&Co., Eli Lilly, Wyeth, Bristol-Myers Squibb, Schering-Plough, Abbott Laboratories, Johnson&Johnson, Medtronic, Boston Scientific*), Japan: 4 (*Takeda, Daiichi Sankyo, Astellas Pharma, Eisai*), Germany: 3 (*Bayer, Merck, Boehringer Ingelheim*), Switzerland: 2 (*Roche, Novartis*), UK (*GlaxoSmithKline*), Denmark (*Novo Nordisk*), Belgium (*UCB*), France/Germany* (*Sanofi-Aventis*), Sweden/UK* (*AstraZeneca*)
Automotive	**17 TNCs** *of which:* Germany: 5 (*Volkswagen, Daimler, BMW, Continental, Bosch*), Japan: 4 (*Toyota Motor, Honda Motor, Nissan Motor, Denso*), US: 3 (*General Motors, Ford Motor, Delphi*), France: 2 (*Renault, PSA Peugeot Citroën*), Sweden (*Volvo*), Italy (*Fiat*), South Korea (*Hyundai Motor*)
Electronic, electrical and IT *(selected segments)*	**11 TNCs** *of which:* Japan: 6 (*Hitachi, Toshiba, Canon, NEC, Ricoh, Sony*), South Korea: 2 (*Samsung Electronics, LG Electronics*), US (*Texas Instruments*), Holland (*NXP*), Italy/France* (*STMicroelectronics*)
Electronic and electrical	**7 TNCs** *of which:* Japan: 4 (*Matsushita Electric Industrial, Sharp, Mitsubishi Electric, Fujifilm*), Germany: 2 (*Siemens, Infineon Technologies*), Holland (*Philips*)
Aerospace and defense	**5 TNCs** *of which:* US: 2 (*Boeing, UTC*), France (*Safran*), Italy (*Finmeccanica*), France/Germany/Spain* (*EADS*)
Others	**13 TNCs** *of which:* US: 8 (*DuPont, Dow Chemical, General Electric, Honeywell International, Procter&Gamble, Amgen, Caterpillar, Applied Materials*); Holland/UK*: 2 (*Unilever, Royal Dutch Shell*); Germany (*BASF*); France (*Areva*), Switzerland (*Nestlé*)

Source: own study based on corporate R&D spending; * – these TNCs were created through merger between companies that originated in the above highlighted countries, and were based in one of these countries (except for Unilever, which was a dual-listed company based in both countries of origin).

As illustrated in Table 3, most of the world's top R&D-active TNCs in 2007 were corporations based in the Triad countries counted among the then largest R&D spenders. Indeed, 72 TNCs (i.e. 70.6% of the group) were based in the top three countries in 2007, i.e. in the United States, Japan and Germany (40, 20 and 12 TNCs respectively). However, this similarity between the home countries of these leading TNCs and the countries being top R&D spenders cannot be interpreted as evidence of the centralisation approach to research and development activity among such corporations. As mentioned in Section 1, R&D-active TNCs have tended to develop their corporate networks of R&D units at international level, yet they have differed widely in the degree of internationalisation of their R&D. Indeed, according to the additional corporate information available, 72 TNCs included in TNC-102 (i.e. 70.6% of the group) had already developed their corporate networks of R&D units

on an international scale by the year 2007, of which 34 corporations had achieved a moderate degree of internationalisation of their in-house R&D, and 38 corporations had achieved an advanced degree[44].

The industry composition of TNC-102 casts a new light on the R&D-active TNCs' role in boosting the world's research and development activity in the context of the two discussed megatrends in science and technology. As illustrated in Table 3, all the world's top corporate R&D spenders in 2007 were the companies operating in industries that were:

a) technology-intensive industries (mostly manufacturing ones),
b) in most cases, also converging industries.

The foundations for such industries are provided by a multidisciplinary science and technology basis, which involves conducting R&D work in diverse fields of S&T. For example[45]:

1. TNCs operating in 'IT and telecommunications' and 'electronic and electrical' industries need to conduct R&D in computer and information sciences, telecommunications, electrical and electronic engineering, automation and control systems, communication engineering and systems, computer hardware and architecture, nanotechnology.
2. TNCs operating in 'health care and pharmaceuticals' need to pay particular attention to chemical sciences, biological sciences, medical and health sciences as well as to medical engineering, bioinformatics, materials engineering.

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[44] While analysing corporate information on the in-house R&D organisation, the author decided to differentiate between the two above-mentioned degrees of R&D internationalisation in the examined TNCs. A moderate degree was assigned to TNCs that still had a predominant R&D base located in their home countries, yet they had also established some R&D units in selected host countries (it corresponded to the 'R&D hub model' in a typology of international R&D organisations proposed by O. Gassman and M. von Zedtwitz in: *New concepts and...*, op. cit., pp. 241–243). An advanced degree was assigned to TNCs that had developed well-coordinated networks of R&D units located in different countries, without a dominant role of home country (it corresponded to the 'integrated R&D network' in the typology by O. Gassman and M. von Zedtwitz in: ibidem, pp. 243–245). Thus, according to the author's research, the moderate international R&D performers were TNCs based in: the United States (15), Japan (13), Germany (3), Belgium (1), Italy (1) and South Korea (1). The advanced international R&D performers were TNCs based in: the United States (11), Germany (7), the United Kingdom (4), France (4), Switzerland (3), Holland (3), Japan (2), South Korea (2), Finland (1), both the UK and Holland (1). It is worth adding that there were only 5 TNCs identified as 'strongly centralised R&D performers' (i.e. corporate R&D facilities were located in their home countries: 4 Europe-based TNCs and 1 Japan-based TNC). There was too little information available for 25 other TNCs included in TNC-102 to identify their approach to the in-house R&D organisation.

[45] Adapted from: K. Poznańska, K.M. Kraj, *Badania i rozwój...*, op. cit., p. 100; the description in the referred to book is based on *Revised Field of Science and Technology (FOS) Classification in the Frascati Manual,* OECD 2007 (DSTI/EAS/STP/NESTI (2006) 19/FINAL).

3. TNCs operating in the 'automotive' industry need to conduct R&D particularly in mechanical engineering, electrical and electronic engineering, automation and control systems, communication engineering and systems.
4. TNCs operating in the 'aerospace and defense' industry need to pay particular attention to computer and information sciences, physical sciences, electrical and electronic engineering, robotics and automation control, mechanical engineering (especially aerospace engineering) and materials engineering.

In other words, the above-discussed industrial profile of TNC-102 indicates that these R&D-active corporations were involved in performing research and development projects in an increasing number of different fields of science and technology, either in-house or in collaboration with different partners. This in turn resulted in rising costs of R&D incurred by these companies.

Indeed, as illustrated in Table 4, the selected group of the world's top 102 corporate R&D spenders increased significantly their R&D expenditure between 2000 and 2011 (by 89%). Two industries, i.e. 'aerospace and defense' and 'health care and pharmaceuticals' (including biotechnologies for life) were the first and second fastest-growing industries in terms of R&D expenditure incurred by TNC-102 (an increase of 207% and 132.9% respectively). The third fastest-growing industry was 'automotive', which included both manufacturers of car parts and car producers (an increase of 92%).

It is also worth mentioning that TNCs operating in the 'IT and telecommunications' and 'electronic and electrical' industries increased their R&D expenditure by less (i.e. 69% and merely 18.9%) than TNCs operating in the selected segments of these converging industries (i.e. 'electronic, electrical and IT': 78.1%). This distinguishing subgroup exemplifies a truly hybrid industry, in which companies need to expand the scope of their R&D activity into more and more fields of science and technology, including new and converging ones.

Despite this long-term upward trend in corporate R&D spending of TNC-102, estimates presented in Table 4 indicate that the last decade's economic turbulence did have an impact on R&D expenditure of the analysed group of 102 R&D-active TNCs.

A comparative analysis of these estimates, at the level of TNC-102 subgroups by industry, leads to the two key findings:

1) During the first subperiod of a downturn in the world economy in the 2000 s (i.e. 2000–2003), the aggregate R&D expenditure was decreasing mostly in the case of subgroups of corporations operating in the industries related to the burst of 'the Internet bubble' (i.e. 'IT and telecommunications' and 'Electronic, electrical and IT'). Subgroups of TNCs operating in other industries were increasing their R&D expenditure, except for some single years in the above subperiod. It is

worth adding that two subgroups of TNCs operating in the industries mentioned before as the fastest-growing ones, i.e. 'aerospace and defense' and 'health care and pharmaceuticals', were continually increasing their R&D expenditure from 2000 through 2003.

2) During the second subperiod of a downturn in the world economy in the 2000s (i.e. 2008–2009), R&D expenditure of nearly all firms from the analysed group of 102 TNCs, i.e. with the exception of corporations operating in 'aerospace and defense', decreased in 2009, which proved to be the year of a severe economic downturn in the world economy. However, the impact of this subperiod of the global economic turbulence on the subgroup of TNCs operating in 'aerospace and defense' was observed at the beginning of this decade – their aggregate R&D expenditure decreased significantly in 2010, yet again increased in 2011.

Undeniably, the impact of the discussed economic turbulence on R&D expenditure incurred by the analysed group of the world's top 102 corporate R&D spenders is reflected in changes of a percentage ratio of their R&D expenditure to the world's aggregate R&D expenditure in the period of 2000–2011. As illustrated in Table 4, the relevant percentage ratio ranged between 27% and 30% in the above period, and the long-term trend appears to have been downward. However, it can be attributable to the fact that some of these TNCs were restructuring their businesses (e.g. divesting some parts) between 2009 and 2011.

Despite this downward trend in their role in global R&D expenditure, the analysed group of the world's top 102 corporate R&D spenders in 2007 accounted for a considerable share of the world's R&D expenditure not only in 2007 alone but also in the discussed period of 2000–2011.

Table 4. The estimates of R&D expenditure of the world's top 102 corporate R&D spenders in 2007, and their changes in the period of 2000–2011 (in total and by industry, and against a background of the estimates of the world's R&D expenditure)

	2000	2001	2002	2003	2004	2005	2006	**2007**	2008	2009	2010	2011	Change 2011/2000
the aggregate R&D expenditure of TNC-102 ($m) *of which:*	**193 595.6**	**194 329.0**	**200 821.5**	**222 679.6**	**244 510.6**	**262 839.2**	**283 625.0**	**317 074.9**	**344 787.5**	**322 606.4**	**332 973.5**	**365 924.9**	**+89.02%**
year-on-year change (%):		*+0.38%*	*+3.34%*	*+10.88%*	*+9.80%*	*+7.50%*	*+7.91%*	*+11.79%*	*+8.74%*	*–6.43%*	*+3.21%*	*+9.90%*	
IT and telecom-munications	50 045.2	49 641.5	49 530.9	51 742.4	53 736.2	57 536.9	65 239.7	75 562.8	81 655.0	74 511.7	77 166.6	84 795.8	+69.44%
Health care and pharmaceuticals	42 315.1	44 056.5	48 295.2	56 000.5	59 480.4	66 164.0	74 675.4	84 762.3	92 369.1	90 754.5	94 673.1	98 562.2	+132.92%
Automotive	43 118.9	42 682.9	46 137.7	52 352.4	58 969.4	63 876.2	63 990.7	71 966.3	80 117.2	68 140.9	70 010.4	82 781.0	+91.98%
Electronic, electrical and IT *(selected segments)*	21 362.2	19 996.3	19 618.0	22 537.5	26 530.6	28 409.3	30 849.5	32 041.9	34 725.8	32 807.2	34 586.2	38 047.9	+78.11%
Electronic and electrical	18 070.8	18 496.0	17 452.5	18 392.5	20 534.9	19 624.8	16 807.3	17 859.6	19 614.4	18 577.6	19 552.5	21 484.3	+18.89%
Aerospace and defense	4 768.2	6 043.8	6 337.5	7 269.8	8 764.7	9 670.6	11 812.5	13 021.6	13 450.4	16 006.1	13 779.0	14 639.1	+207.02%
Others	13 915.2	13 412.0	13 449.7	14 384.5	16 494.4	17 557.4	20 249.9	21 860.4	22 855.6	21 808.4	23 205.7	25 614.6	+84.08%
	The aggregate R&D expenditure of TNC-102 as a percentage of the world's R&D expenditure for a relevant year:												
	29.8%	29.9%	30.7%	30.1%	29.7%	30.1%	30.0%	30.1%	29.1%	27.8%	27.3%	27.0%	

Source: own study based on corporate R&D spending and estimates based on the UIS 'Science, Technology & Innovation' database ('June 2013 release' and 'July 2014 release') and the World Bank's WDI database (July 2014 update).

5. Conclusion

Transnational corporations played a vital role in making the world's research and development activity more dynamic during the decades of the 1970s through the 2000s. These companies were not only increasing their R&D expenditure as a whole, but they were also decentralising their in-house R&D operations on an international scale through developing their corporate networks of R&D units located in selected host countries, both developed and the fast-developing ones.

According to the results of the author's research, the group of 102 largest corporate R&D spenders worldwide in 2007 played an important role in the world's R&D activity in the whole period of 2000–2011, despite the fact that the decade of the 2000s was marked by economic fluctuations in the world economy. The percentage ratio of the aggregate R&D expenditure of this group of R&D-active TNCs to the world's R&D expenditure estimates was significant in the above period. However, the findings of this research also support, in general, the view of many researchers that the level of R&D expenditure of the business sector tends to be procyclical since the analysed corporations were reacting to the economic turbulence in the 2000s by adjusting their current level of R&D expenditure.

Furthermore, all the world's top R&D-active corporations in 2007 were operating in technology-intensive industries (mostly manufacturing ones), thereby conducting research and development in many diverse fields of science and technology as these laid the foundations for their industry profile. Thus it can be assumed that these R&D-active TNCs contributed to further convergence of existing fields of S&T as well as to emergence of new ones in the analysed period of 2000–2011.

It is also worth adding that the results of the author's research discussed in this paper suggest that the future distribution of the major regions and countries by their importance in the world's R&D activity will be strongly dependent on the current trends in internationalisation of corporate R&D activity. Although internationalisation of corporate R&D brings in both advantages and disadvantages to countries involved in this process, nowadays no country can significantly improve its science and technology base without attracting any form of corporate R&D activity, preferably corporate R&D units.

Thus R&D-oriented countries need to seek to develop their domestic science base as well as the higher education sector with a particular focus on the converging fields of science and technology as these provide the foundations for technology-intensive industries, in which most of the largest corporate R&D spenders tend to operate.

References

1. Behrman J.N., Fischer W.A., *Overseas R&D Activities of Transnational Companies,* Oelgeschlager, Gunn & Hain, Cambridge, MA 1980.
2. Boutellier R., Gassmann O., von Zedtwitz M., *Managing Global Innovation. Uncovering the Secrets of Future Competitiveness*, Springer-Verlag, second revised edition, Berlin Heidelberg 2000.
3. Castellani D., Zanfei A., *Multinational Firms, Innovation and Productivity*, Edward Elgar Publishing, Cheltenham/Northampton 2006.
4. Doz Y., Santos J., Williamson P., *From Global to Metanational: How Companies Win in the Knowledge Economy*, Harvard Business School Press, Boston MA 2001.
5. Dunning J.H., *Multinational Enterprises and the Global Economy*, Addison-Wesley, Workingham 1992.
6. Gassmann O., von Zedtwitz M., *New Concepts and Trends in International R&D Organization*, "Research Policy" 1999, vol. 28, iss. 2–3 (Special Issue).
7. Gerybadze A., Reger G., *Globalization of R&D: Recent Changes in the Management of Innovation in Transnational Corporations*, "Research Policy" 1999, vol. 28, iss. 2–3 (Special Issue).
8. Gilpin R., *The Challenge of Global Capitalism. The World Economy in the 21st Century*, Princeton University Press, Princeton 2000.
9. *Globalization of R&D and Developing Countries*, Proceedings of the Expert Meeting. Geneva 24–26 January 2005, UNCTAD, New York–Geneva 2005.
10. Hemmert M., *International Organization of R&D and Technology Acquisition Performance of High-Tech Business Units*, "Management International Review" 2003, vol. 43(4).
11. Jaruzelski B., Dehoff K., Bordia R., *The 2005 Global Innovation 1000 Study: Money Isn't Everything*, Booz & Co., "strategy+business" 2005, Winter, iss. 41, https://www.strategyand.pwc.com/global/home/ what-we-think/51025132/past-year-studies (18.04.2017).
12. Jaruzelski B., Dehoff K., *The 2010 Global Innovation 1000 Study: How the Top Innovators Keep Winning*, Booz & Co., "strategy+business" 2010, Winter, iss. 61, https://www.strategyand.pwc.com/global/home/ what-we-think/51025132/past-year-studies (18.04.2017).
13. Kraj K.M., *Corporate R&D Centres in Poland*, in: *Przedsiębiorstwo wobec wyzwań globalnych*, eds. A. Herman, K. Poznańska, vol. 2, SGH, Warsaw 2008.
14. Kuemmerle W., *Building Effective R&D Capabilities Abroad*, "Harvard Business Review" 1997, March-April.

15. Kumar N., *Multinational Enterprises, Overseas R&D Activity and the Global Technological Order*, Research and Information System, New Delhi 1999.
16. Medcof J.W., *A Taxonomy of Internationally Dispersed Technology Units and Its Application to Management Issues*, "R&D Management" 1997, October, vol. 27, iss. 4.
17. Niosi J., *The Globalization of Canada's R&D*, "Management International Review" 1997, vol. 37(4).
18. Patel P., Vega M., *Patterns of Internationalisation of Corporate Technology: Location vs Home Country Advantages*, "Research Policy" 1999, vol. 28, iss. 2–3 (Special Issue).
19. Pearce R.D., *Decentralised R&D and Strategic Competitiveness: Globalised Approaches to Generation and Use of Technology in Multinational Enterprises (MNEs)*, "Research Policy" 1999, vol. 28, iss. 2–3 (Special Issue).
20. Poznańska K., Kraj K.M., *Badania i rozwój w korporacjach transnarodowych. Organizacja. Umiędzynarodowienie*, Wydawnictwo Naukowe PWN, Warsaw 2015.
21. Reddy P., *Globalization of Corporate R&D: Implications for Innovation Systems in Host Countries*, Routledge, London–New York 2000.
22. *Regions, Globalization, and the Knowledge-Based Economy*, ed. J.H. Dunning, Oxford University Press, Oxford–New York 2000.
23. *Revised Field of Science and Technology (FOS) Classification in the Frascati Manual*, OECD 2007 (DSTI/EAS/STP/NESTI(2006)19/FINAL).
24. Roberts E.B., *Benchmarking Global Strategic Management of Technology*, "Research Technology Management" 2001, March–April, vol. 44, no. 2.
25. Ronstadt R., *Research and Development Abroad by U.S. Multinationals*, Praeger Publishers, New York 1977.
26. *Technical Change and the World Economy: Convergence and Divergence in Technology Strategies*, ed. J. Hagedoorn, Edward Elgar Publishing, Cheltenham–Northampton 1995.
27. Tellis G.J., Eisingerich A.B., Chandy R.K., Prabhu J.C., *Competing for the Future: Patterns in the Global Location of R&D Centers by the World's Largest Firms,* Working Paper, Centre for India & Global Business, University of Cambridge – Judge Business School, 2009, www.india.jbs.cam.ac.uk/research/facultyresearch.html (24.03.2009).
28. *The 1991 R&D Scoreboard*, http://webarchive.nationalarchives.gov.uk/20101208170217/http://www.innovation. gov.uk/rd_scoreboard/?p=31 (8.04.2017).
29. *The 2000 R&D Scoreboard*, http://webarchive.nationalarchives.gov.uk/20101208170217/http://www.innovation. gov.uk/rd_scoreboard/?p=31 (8.04.2017).
30. *The 2004 EU Industrial R&D Investment Scoreboard*, European Commission, DG-JRC/DG-RTD, http://iri.jrc.ec.europa.eu/scoreboard.html (18.04.2017).
31. *The 2004 R&D Scoreboard*, UK DTI, http://webarchive.nationalarchives.gov.uk/20101208170217/http://www.innovation.gov.uk/rd_scoreboard/?p=31 (8.04.2017).

32. *The 2010 EU Industrial R&D Investment Scoreboard*, European Commission, JRC/DG-RTD, http://iri.jrc.ec.europa.eu/scoreboard.html (18.04.2017).
33. *The 2010 R&D Scoreboard*, UK BIS, http://webarchive.nationalarchives.gov.uk/20101208170217/http://www.innovation.gov.uk/rd_scoreboard/?p=31 (8.04.2017).
34. *The Internationalisation of Business R&D. Evidence, Impacts and Implications*, OECD, Paris 2008.
35. The UIS 'Science, Technology & Innovation' database ('June 2013 release' and 'July 2014 release'), http://data.uis.unesco.org/
36. The World Bank's 'World Development Indicators' database, July 2014, http://data.worldbank.org/data-catalog/world-development-indicators
37. *World Investment Report 2005: Transnational Corporations and the Internationalization of R&D*, UNCTAD, New York–Geneva 2005.