Innovation by MNEs in emerging markets

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Innovation is a key competitive advantage for companies in the 21st century. R&D and other innovative work was traditionally carried out by MNEs in their home countries, although it spread to some affiliates in other developed countries in the late 20th century, and to some emerging markets more recently. This paper analyzes the assignment of innovative activity, particularly R&D, by MNEs to their affiliates in emerging markets. Using both aggregate data produced by government organizations and company-specific interviews and published commentaries, we find that MNEs assign more responsibility for R&D and innovation to affiliates in emerging markets that have larger markets, lower human resource costs, greater overall R&D activity and to some extent greater activity of the company in question. China and India are huge exceptions to the rule that MNEs tend to assign only development work to emerging market affiliates: they are increasingly assigning core R&D to these two large countries. Corporate strategy can be adjusted to take advantage of low-cost R&D capabilities, particularly in these large markets, and to pull innovations from those affiliates throughout the rest of the firm. Public policy to attract R&D by MNEs should look at offering companies better access to sizable markets, offering incentives for R&D activity and building up R&D activity in the local economy, by companies and government alike.

Keywords: emerging markets, innovation, MNEs, new technology, R&D

1. Introduction

Innovation is one of the most important competitive advantages of the 21st century (Rubera and Kirca 2012; Pisano 2015; Grosse 2015; Chatzoglou and Chatzoudes 2018). Countries as well as companies are interested in stimulating more innovative activity and benefitting from the outcomes (e.g. income, jobs, profits, prestige).

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Many efforts are underway in various countries to try to create a new Silicon Valley or a new Silicon Allee (as in Berlin). Companies large and small, in high-tech and low-tech industries, are aware of the advantages generated by being in the vanguard with new technology, whether it be patented products and processes or unpatented activities such as management of customer relations or internal company information.[1]

The overarching aim of this paper is to explore in detail the expansion of research and development (R&D) activity by traditional multinational corporations (MNEs) (i.e., from the United States, Western Europe and Japan, or the "Triad") into emerging markets. Historically, innovative activity within MNEs was largely limited to the home country and other high-income industrial countries. In the 21st century, companies have discovered compelling reasons to carry out some of their R&D in emerging markets, particularly the largest ones, China and India. With a better understanding of the motivations of companies, governments in emerging markets can pursue public policies to try to attract more of that activity and generally to guide multinationals into providing greater spillover benefits to the host country from their activities. The contribution of this paper is to demonstrate what motivates companies to put innovative activity in emerging markets and to show how government policies and government relations with MNEs have encouraged or discouraged such innovation.

Multinational firms have traditionally carried out their core innovative activities – particularly industrial R&D – in the home country, with occasional extensions to Triad countries (Ronstadt 1978; Patel and Pavitt 1991; Reddy 2000; Belderbos et al. 2013). In the past few decades, MNEs have established R&D activities in emerging markets as well (e.g. UNCTAD 2005a, b; Egan 2017). Initially, these activities were mainly to adapt products and processes to local conditions in emerging markets. In recent years, core R&D itself has sometimes moved to emerging market affiliates, particularly in the very large markets of China and India (OECD 2008, p. 8ff; Gassmann and Han 2004; Yip and McKern 2014). This paper looks at the process of innovation by multinational firms as it is carried out in overseas affiliates, concentrating on emerging markets.

Although innovation can occur in all aspects of business, from production to distribution to the organization of the company and much more, our main focus is on the creation and implementation of product and process technology for which evidence is available. This activity can be measured by indicators such as R&D spending by companies or, in many cases, by the number of patents registered

[1] It should be noted that there are patented systems for both customer relationship management and company data management, for example, those sold by SAP and Oracle.

with the United States Patent and Trademark Office (USPTO), or with some other indicator that perhaps covers the creation of new knowledge and its implementation in business more broadly. Our empirical analysis looks at innovation as captured by various measures of R&D activity along with several more detailed company discussions, and we also consider some issues related to unmeasured innovation activity.[2]

Looking around the world, it is clear that far less R&D activity takes place in Latin America, Africa and most of Asia than elsewhere. Why do companies invest so little in R&D in these emerging markets in comparison with the United States, the European Union (EU), Japan and China? If we compare just emerging markets among themselves, R&D investment in Latin America, Africa and most Asian countries still falls far short of that in China, India, the Czech Republic, South Korea, Israel[3] and a small number of other countries. Table 1a shows the amount of R&D activity in selected countries as a percentage of GDP, and table 1b shows the amount of R&D undertaken by United States multinationals in their foreign affiliates.

Note that the R&D activity in table 1a relates to *all* R&D in each country, including not just companies but the government sector and universities as well. In this ranking, the United States, Japan, the Nordic countries, Germany, Switzerland, Israel, South Korea and China stand out above all others.

In table 1b the R&D spending is that of United States-based multinational companies in their foreign affiliates. Although the data relate only to United States companies, they are probably fairly representative of foreign investors in general in the various countries. These data also show Japan, the Nordic countries, Germany, Switzerland, Israel and China, along with the United Kingdom and India, as top locations for R&D activities by United States MNEs.

Before proceeding to explore innovation in MNE affiliates in detail, it is useful to consider why it is so important. For a company to compete successfully, it needs competitive advantages relative to other companies. Some competitive advantages may come from historical accident or luck: they may involve access to a scarce natural resource such as oil or gold, or a good climate for a primary industry such as farming or fishing. One competitive advantage that does not require any particular physical location, and thus can exist for companies anywhere, is innovation.

[2] The very important area of business model innovation (e.g., Amit and Zott 2012; Chesbrough 2010) should be included as well, but for lack of measures and data, we leave it aside here, except for some commentary. Similarly, services-sector R&D is quite important in many business services, but it has not been measured in any consistent way, so it is discussed here only in commentary.

[3] Even here, three of these five countries (viz., the Czech Republic, Israel and South Korea) are members of the OECD, so arguably the only emerging markets with a high level of R&D activity are China and perhaps India.

Table 1a. R&D spending as a percentage of GDP, selected countries, 1996–2015

Country	1996	2000	2005	2010	2014	2015
Argentina	0.42	0.44	0.38	0.52	0.61	n.a.
Australia	1.66	1.58	2.18	2.38	2.20	n.a.
Belgium	1.73	1.92	1.78	2.05	2.46	2.46
Brazil	n.a.	1.00	1.00	1.16	1.24	n.a.
Canada	1.62	1.87	1.99	1.84	1.61	n.a.
China	0.57	0.90	1.32	1.73	2.05	2.07
Colombia	0.30	0.11	0.15	0.20	0.20	0.24
Costa Rica	0.30	0.39	0.43	0.48	0.56	n.a.
Czech Republic	0.90	1.12	1.17	1.34	2.00	1.95
Denmark	1.81	2.20	2.39	2.94	3.08	3.01
Egypt	0.21	0.19	0.24	0.42	0.68	0.72
Finland	2.45	3.25	3.33	3.73	3.17	2.90
France	2.21	2.08	2.04	2.18	2.26	2.23
Germany	2.14	2.39	2.42	2.71	2.87	2.88
Hungary	0.63	0.79	0.93	1.15	1.37	1.38
India	0.63	0.74	0.81	0.80	0.82	0.63
Indonesia	n.a.	0.07	n.a.	0.08	0.08	n.a.
Ireland	1.27	1.09	1.19	1.61	1.52	n.a.
Israel	2.60	3.93	4.04	3.93	4.11	4.27
Italy	0.95	1.01	1.05	1.22	1.29	1.33
Japan	2.77	3.00	3.31	3.25	3.58	3.28
Malaysia	0.23	0.47	0.60	1.04	1.26	1.30
Mexico	0.26	0.32	0.40	0.45	0.54	0.55
Netherlands	1.86	1.81	1.79	1.72	1.97	2.01
Poland	0.65	0.64	0.57	0.72	0.94	1.00
Russian Federation	0.97	1.05	1.07	1.13	1.19	1.13
Singapore	1.32	1.82	2.16	2.01	2.19	n.a.
South Africa	0.58	0.72	0.86	0.74	0.73	n.a.
South Korea	2.24	2.18	2.63	3.47	4.29	4.23
Spain	0.79	0.88	1.10	1.35	1.23	1.22
Sweden	3.32	3.91	3.39	3.22	3.16	3.26
Switzerland	2.45	2.33	2.68	2.73	2.97	n.a.
Thailand	0.12	0.24	0.22	0.36	0.48	0.63
Turkey	0.45	0.48	0.59	0.84	1.01	n.a.
United Kingdom	1.71	1.72	1.63	1.69	1.70	1.73
United States	2.44	2.62	2.51	2.74	2.73	2.79
OECD	2.14	2.30	2.22	2.38	2.42	2.55
World	**1.99**	**2.08**	**1.99**	**2.05**	**2.12**	**2.23**

Source: World Bank, *World Development Indicators,* http://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS.

Table 1b. R&D performed abroad by majority-owned foreign affiliates of United States parent companies, by region/country, selected years, 1982–2015 (Millions of current U.S. dollars)

	1982	1989	1995	2000	2005	2010	2013	2015
Total	3,851	7,922	12,582	19,758	27,653	36,991	48,750	54,797
Manufacturing	3,247	6,446	10,791	17,822	23,508	29,385		
Total expenditures by region/country								
Canada	505	975	1,068	1,874	2,433	3,040	3,148	3,430
Europe	2,892	5,475	9,144	12,938	18,805	24,155	29,825	31,274
Belgium	223	313	292	410	920	1,259	2,608	1,125
France	332	521	1,271	1,445	2,248	2,171	2,359	2,213
Germany	1,079	1,726	3,068	3,105	4,609	7,039	8,272	8,033
Ireland	9	156	171	518	820	1,503	1,858	2,994
Italy	150	393	346	575	580	582	806	835
Netherlands	65	367	495	369	392	1,484	1,478	1,173
Spain	40	58	288	196	257	379	284	380
Sweden	28	31	691	1,335	1,652	1,576	670	708
Switzerland	60	59	242	220	878	1,123	3,735	3,865
United Kingdom	824	1,718	1,935	D	5,406	5,157	5,346	6,165
Asia and Pacific	238	1,272	1,865	3,727	4,764	7,210	10,712	14,425
China						1,579	2,179	3,428
India						1,377	2,557	3,216
Japan	112	1	1,286	1,433	1,717	1,872	2,070	2,438
Australia	114	190	287	330	556	923	1,114	1,039
Singapore	D	24	63	548	576	621	642	1,755
Latin America and the Caribbean	169	155	389	665	841	1,465	2,750	2,374
Argentina						92	161	151
Brazil	97	92	249	250	405	791	1,224	883
Mexico	30	37	58	305	D	329	389	666
Middle East	11	33	97	527	770	1,063	2,187	3,150
Israel	11	29	97	527	767	1,060	2,153	2,955
Saudi Arabia	—	4	—	0	3	4	D	16
Africa	25	11	19	27	40	57	128	145
Egypt						6	3	43
South Africa	23	9	17	22	31	43	94	38

— = less than $500,000.

D = data withheld to avoid disclosing operations of individual companies.

Source: U.S. Department of Commerce, Bureau of Economic Analysis, Survey of U.S. Direct Investment Abroad, annual series, http://www.bea.gov/bea/di/di1usdop.htm and http://www.nsf.gov/sbe/srs/seind04/append/c4/at04-51.xls and http://www.bea.gov/international/pdf/fdius_2009p/II%20H1%20to%20H6.pdf.

Note: Data are for majority-owned (more than 50 per cent ownership) non-bank foreign affiliates of non-bank United States parents. Data include R&D expenditures made by affiliates, whether for themselves or for others, under contract. Data exclude R&D expenditures made by others for affiliates under contract. Manufacturing data exclude petroleum manufacturing before 1999.

This kind of advantage can be built, in principle, by any company that is able to identify a need for any product, service or process, and fill it with a new product, service or process. So, innovation allows (companies from) any country, large or small, landlocked or maritime, highly developed or less developed, to pursue potentially sustainable advantages that are based on investment in innovative activities.[4]

The next section looks at why MNEs undertake R&D outside of their home countries. The third section discusses the kinds of activity that constitute innovation and the measures that exist for international comparisons. The subsequent section presents the conceptual structure of the paper, including four hypotheses about the features of companies and countries that are expected to produce greater R&D activity by MNE affiliates. The next section presents empirical evidence and tests of the hypotheses. The final section draws some conclusions, proposes policy options for attracting private sector-led R&D, and suggests directions for future research.

2. Why do MNEs undertake R&D outside of their home countries?

Perhaps 30 years ago or earlier, this was a simple question, and one that had been answered in various studies in the 1970s and 1980s (e.g., Ronstadt 1978) by one general purpose: to carry out local development of products to adapt them to local demand and cost conditions. Even here the answer was somewhat more nuanced. Ronstadt found that some MNEs had acquired companies abroad that conducted their own R&D, so these acquired affiliates had fairly independent R&D activity – though still focused on their local markets. He also found that some overseas R&D was used to adapt products imported from the home country to local conditions, whereas other R&D was done to develop new products for that local market. Finally, he found that in a handful of cases, MNEs operated R&D units outside the home country that had a global orientation, creating products for sale in various countries where the firm operated.

After Ronstadt's early exploration of this subject, a number of other authors entered the discussion, to the point where today one could classify overseas R&D by multinational firms as belonging to four categories (e.g., Egan 2017; Jha et al. 2018):

[4] Of course, this ignores the institutional conditions that make it very difficult to innovate successfully in business in North Korea or the Central African Republic, in comparison with, say, Luxembourg or South Korea.

i. Adapting products originally made elsewhere to local market conditions in the foreign country, that is, product development in the definition of the United States National Science Foundation (NSF) (see below).

ii. Carrying out R&D that could be applied in the home country and elsewhere, because the cost conditions in the host country are favourable in comparison with those of the home country.

iii. Carrying out R&D in a location where other firms in the same industry are doing R&D, to learn from the innovation environment.

iv. Participating in a global network of R&D activity of the firm, on the basis of costs, market features and the availability of knowledge and/or skills.

Under 2, there is a phenomenon labelled "reverse innovation" (e.g. Govindarajan and Ramamurti 2011) in which MNEs use R&D in relatively low-cost emerging market locations to develop or create products and processes that can be applied in the home country and in the rest of the world. To date, this phenomenon has largely been confined to the very large markets of China and India, but the phenomenon of using skilled technical or managerial resources in emerging markets to develop a medical device (e.g. the Lullaby baby warmer by GE in India) or to develop electric cars (by General Motors and Volkswagen in China) is a practice that likely will become more common in the near future as emerging markets grow in importance globally.

As global transport and communications costs have fallen, MNEs have moved to distribute parts of their R&D activities according to these four motives. The analysis in this paper looks only at the activities assigned to emerging-market affiliates of these companies.

3. Types and measures of R&D activity

3.1. Types of R&D activity

Consider the three kinds of scientific R&D that are studied by the NSF – basic, applied and development. ***Basic research*** is generally not pursued by companies in developed countries or in emerging markets. Most of this kind of research is in the domain of universities and government-sponsored programs. Since, by definition, basic research is aimed at discovering new knowledge, which may not necessarily be applicable to business, this is logical. And when government wants to pull firms into such research, the R&D is typically heavily subsidized at government expense. In any event, basic research is largely outside of the scope of industrial, corporate research activity.

Applied research, in contrast, is exactly the kind of activity that is preferred by business, and by MNEs in particular. This research includes the following efforts:

a. creating new products (for local or worldwide use)

b. creating new processes for producing and distributing goods and services

c. adapting products to local circumstances

d. adapting processes to local circumstances

Applied research in emerging markets is a relatively small but growing part of R&D activity carried out by MNEs in overseas affiliates, as they adjust their products, services and processes to the local environment. Major R&D in emerging markets occurs in some automotive firms such as Volkswagen in China and General Motors in Brazil and China, as well as in some information technology and telecommunication firms such as Motorola in Brazil, Samsung in China, and IBM and Microsoft in India.

Development is defined by the NSF as the "systematic application of knowledge or understanding, directed toward the production of useful materials, devices, and systems or methods, including design, development, and improvement of prototypes and new processes to meet specific requirements"[5]. This activity is pursued extensively by MNEs in their operations in several emerging markets. (See, for example, Cassiolato 2001; UNCTAD 2005; Svartzman 2008; Haakonsson et al. 2015; Jha et al. 2018.) This part of R&D may in fact be the most important for these companies in emerging markets, since their efforts often involve the adaptation of existing products or processes to the local context.[6]

3.2. Measures of R&D activity in emerging markets

3.2.1. Patents from emerging-market registrants in the United States

This kind of data is available annually for "new invention" patents and for all patents, and is also identified by the country of the person or institution that files the patent. In addition, the USPTO has data by company; and the World Intellectual Property Organization (WIPO) has data for filings in the United States by companies from several dozen countries. The USPTO data allow for the identification of patents obtained by emerging-market affiliates of United States companies; as shown in tables 2a and 2b. The data are quite instructive about the level of scientific research in manufacturing and extractive industries, where patent protection is often a good

[5] https://wayback.archive-it.org/5902/20160210164701/http://www.nsf.gov/statistics/randdef/fedgov.cfm.

[6] This is called "tropicalization" in Latin America.

Table 2a. Patent counts by country and year (all patents, all types), 1 January 1977–31 December 2015

State/Country	1977–1982	1983–1987	1988–1992	1993–1997	1998–2002	2003–2007	2008–2012	2013	2014	2015	Total
Argentina	130	94	102	164	271	249	234	75	71	66	1,456
Brazil	144	136	230	326	536	705	790	254	334	323	3,778
Chile	17	15	25	35	73	86	n.a.	n.a.	n.a.	n.a.	251
China	--	--	830†	--	--	2,531	13,343	5,928	7,236	8,116	37,984
Hungary	--	--	583	--	--	262	408	134	159	143	1,689
India	--	--	728	--	--	2,116	5,336	2,424	2,987	3,355	16,946
Israel	--	--	5,955	--	--	5,470	8,844	3,012	3,472	3,628	30,381
Malaysia	--	--	210	--	--	489	883	214	259	256	2,311
Mexico	244	203	207	250	463	468	427	155	172	172	2,761
Russian Federation	--	--	1,153	--	--	880	1273	417	444	440	4,607
Singapore	--	--	1,149	--	--	2,027	2,895	797	946	966	8,780
South Africa	--	--	1,187	--	--	490	565	161	152	166	2,721
South Korea	--	--	20,883	--	--	24,926	53,476	14,548	16,469	17,924	148,226
Venezuela, Bolivarian Republic of	51	79	112	149	160	85	n.a.	n.a.	n.a.	n.a.	636

Source: USPTO, http://www.uspto.gov/web/offices/ac/ido/oeip/taf/cst_all.pdf.

Note: Data for 1977-2002 are grouped for several countries into the middle of that range in the table.

Some multinational firms register patents produced by their overseas affiliates as part of the United States company, thus undercounting the number of patents filed by emerging-market entities (affiliates).

† = Disaggregated data for years before 2003 were not available for several countries. For these countries the total for years before 2003 is shown in the middle column of the five periods.

Table 2b. WIPO list of patents filed in the United States from the listed source countries

	Patents filed in the United States originating from the countries below									
	1996–2000	2001–2005	2006–2010	2011	2012	2013	2014	2015	2016	Total
Argentina	206	238	197	49	63	75	71	66	82	1047
Brazil	388	457	590	215	196	254	334	323	310	3066
Chile	0	35	95	35	37	54	63	75	48	442
China	389	1587	6970	3174	4637	5928	7236	8116	10462	48499
Hungary	193	274	299	100	105	134	159	143	177	1584
India	410	1514	3438	1234	1691	2424	2987	3355	3657	20710
Israel	3298	5155	6714	1981	2474	3012	3471	3628	3713	3446
Malaysia	0	218	783	161	210	214	259	256	275	2376
Mexico	293	425	336	90	122	155	172	172	224	1989
Russian Federation	780	953	1004	298	331	417	445	440	511	5179
Singapore	0	1222	2243	647	810	797	946	966	979	8610
South Africa	548	533	491	123	142	161	152	166	181	2497
South Korea	13519	20048	40185	12262	13233	14548	16469	17924	19494	167682
Venezuela, Bolivarian Republic of	0	45	59	18	25	14	12	22	8	203

Source: WIPO.

mechanism for protecting proprietary knowledge. Such data are not helpful for the services sector, where patents on key knowledge tend not to be feasible. The data presented in table 2a are for all patents registered (granted) in the United States by residents of selected emerging markets for the period 1977–2015.

The patent rates have jumped noticeably in China, India, Brazil and the Russian Federation since the economic opening that began in the early 1990s, with all of these countries surpassing other emerging markets (unless we consider the Asian Tigers – South Korea, Singapore, Taiwan Province of China and Hong Kong, China – to be emerging markets). Table 2b shows patents registered by residents of selected emerging markets in the United States. And if we compare the patent rates to the previous measures of national R&D spending and United States MNE R&D spending, the same countries rank at the top of the list: the United States, Japan, the Nordic countries, Germany, Switzerland, Israel and China. In the case of patents, South Korea, France, the United Kingdom, Canada and Italy also rank near the top of the list.

The aggregate list mentioned earlier does not identify patent registrants by company or name. These data were available only in summary form by country, as shown in the table. Additional data from the USPTO identify patents registered to individuals and companies as well. This list was dominated by affiliates of MNEs for the patents that were listed individually. In China the list includes hundreds of domestic Chinese companies over the past 10 years, along with some subsidiaries of MNEs. A shorter list from the most recent compilation for a somewhat smaller emerging market, Mexico, is shown in table 3.

Note again that this indicator identifies only results of R&D activity that are subject to patent protection, leaving out all other R&D that does not produce such results.[7] In the case of Mexico, the patents come from both companies and research universities, and the number of foreign MNE affiliates is fairly small.

3.2.2. R&D activity of United States-based MNEs in various regions

Looking at the distribution of total R&D activity by United States MNEs in their affiliates around the world over time, table 1b showed that the amount of R&D in emerging markets has grown quite substantially since the end of the 1980s. Nonetheless, the evidence shows that this R&D has grown much more rapidly in the BRIC countries (Brazil, the Russian Federation, India and China) than in most other emerging markets. Based on the data in the table, China is by far the largest emerging-market target of United States firms for offshore R&D, and Brazil and India

[7] Similar patent information for other emerging markets is available at http://www.uspto.gov/web/offices/ac/ido/oeip/taf/reports.htm.

Table 3. Patenting by ownership location country, by organization, 2011–2015

First-Named Owner (Assignee)	Category	2011	2012	2013	2014	2015	Total
Individually Owned Patent	Patent Counts	17	29	42	39	33	160
Grupo Petrotemex, S.A. de C.V.	Patent Counts	18	16	8	8	4	54
Mexichem/Amanco Holding S.A. de C.V.	Patent Counts	0	2	9	10	10	31
Instituto Mexicano del Petroleo	Patent Counts	3	2	4	7	11	27
Mabe, S.A. de C.V.	Patent Counts	1	3	4	6	2	16
Universidad Nacional Autonoma de Mexico	Patent Counts	0	2	5	4	3	14
RFID Mexico, S.A. de C.V.	Patent Counts	4	3	1	1	0	9
Coflex S.A. de C.V.	Patent Counts	1	0	1	3	2	7
Instituto Technologico y de Estudios Superiores de Monterrey	Patent Counts	0	3	1	2	1	7
Sabritas, S. de R.L. de C.V.	Patent Counts	5	1	1	0	0	7
Vitalmex Internacional S.A. de C.V.	Patent Counts	0	1	1	3	2	7
Nucitec S.A. de C.V.	Patent Counts	0	2	1	2	1	6
Universidad de Guanajuato	Patent Counts	0	1	1	4	0	6
Vidrio Plano de Mexico, S.A.	Patent Counts	1	1	2	1	1	6
Centro de Investigacion en Materiales Avanzados S.C.	Patent Counts	0	2	0	2	1	5
Ragasa Industrias, S.A. de C.V.	Patent Counts	0	0	0	3	2	5
Universidad Autonoma Metropolitana	Patent Counts	0	1	3	1	0	5

Source: USPTO, "U.S. Patent Data by Country of Utility Patent: Count of 2005–2011 Utility Patent Grants, by Calendar Year of Grant," http://www.uspto.gov/web/offices/ac/ido/oeip/taf/reports.htm and http://www.uspto.gov/web/offices/ac/ido/oeip/taf/asgstc/mxx_ror.htm.

Note: Utility patents of first-named owners (assignees) located in Mexico.

rival European countries for this activity. The main targets of offshore R&D remain the United Kingdom and Germany. It is still not clear why Latin America, Africa and Asia (excluding China) have not achieved a higher part of the total worldwide R&D by MNEs.[8]

3.3. A comment on missing indicators of R&D in service sectors and in business models

As one might expect, there exists significant R&D activity in *services sectors* such as computer software design and telecommunication services, as well as management consulting and banking. These services are usually left out of measures of R&D, largely because firms providing the services do not have traditional research scientists employed for that purpose and because they generally do not patent their technology.[9] Even so, the people who carry out R&D at such services firms are creating new knowledge that is applied to business and thus should be included in overall R&D activity. This is important in the present context, because services constitute over half of most emerging-market economies, and firms in these regions are clearly doing R&D in the services sector. Although most discussion of services sector R&D is left out of this paper, we do offer below a couple of examples of this activity in India and China. Additional major examples are presented in discussions of R&D activity in India and China in UNCTAD's *World Investment Report 2005*, as well as in OECD (2007), and in Jha et al. (2018) on India, and Motohashi (2010) on China.

Business model innovation should also be considered in the overall analysis of innovation in emerging markets, especially in the cases of China and India, where local and foreign companies are launching platforms for financial services provision (such as Ant Financial, based in China) and for online market operation (as offered by Alibaba, also based in China). In India, business process outsourcing companies including locals Wipro, Tata Consulting and Infosys, along with foreign firms IBM and Microsoft, are developing new models for these activities to compete both locally and globally. Unfortunately, business models are not measured in any systematic way, so their inclusion in this discussion has to be through examples.

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[8] One of the reasons that Asian countries have attracted a larger portion of United States companies' R&D activities than Latin American countries may be the much greater FDI in ICT in Asia. This industry tends to undertake more R&D.

[9] A reasonable amount of patent activity is done on telecommunication and computer hardware, but software is generally more difficult to protect with patents.

4. Conceptual base

On the basis of the findings of research on overseas R&D by multinational firms in the past three decades, we expect investment in this activity in emerging markets to be driven by four motives. Therefore, the following hypotheses will be tested.

Hypothesis 1: *R&D activity by MNE affiliates will be greater where the local market size is larger*.

As clearly evidenced by the amount of corporate R&D taking place in the United States, the EU and Japan, as well as in the BRIC countries, multinationals have moved a large amount of their research work to other countries. In the emerging markets it appears that it is mostly development work that has been transferred, where adaptation to local tastes, rules and purchasing power favour products that meet these criteria. China is the exception here and to some extent India as well, because in many cases in these countries companies are carrying out R&D for global application. This is interesting in contrast to the late 20th century, when governments tried to force MNEs to transfer more skills and activities to host countries but were largely rebuffed except on the issue of product adaptation. Now R&D is being assigned increasingly to emerging-market affiliates for the creation of new products that may have application primarily in the local market, but which are not just off-the-shelf products from the firm's home country. Market size is noted as a key attractor in many studies of emerging-market R&D activity by MNEs (e.g., EU 2012; Birkinshaw and Hood 1998; Egan 2017).

Hypothesis 2: *R&D activity by MNE affiliates will be greater where local cost conditions are lower*.

As MNEs become more confident that their intellectual property can be protected locally in many emerging markets, they have moved to rationalize their R&D around the world to achieve cost savings. Especially in India, with large numbers of English-speaking engineers and other technical people, companies have found it attractive to do research (especially IT-related), where salaries are one-third or less of those in the United States or the EU (Jha et al. 2018; OECD 2008; Reddy 2011). And more broadly in emerging markets around the world, cost conditions have been noted as a key attractor of foreign direct investment (FDI) by MNEs in research activity (Lewin et al. 2009; Egan 2017). Now that people can collaborate around the globe in real time (with only time zones remaining as a barrier), scientists and engineers in far-flung affiliates can work side by side with those in the home office of a company, again allowing for major cost savings.

Hypothesis 3: *R&D activity by MNE affiliates will be greater where local R&D or innovation activity is greater*.

The 1990s saw the start of a tendency for companies to place some of their R&D activity in locations where many companies are involved in such activity. Foreign and United States companies have flocked to Silicon Valley to both do their own research and to learn what other companies are doing there. The learning can come from hiring scientific people away from local firms as well as from finding skilled people to migrate to such locations because they are "where the action is". This is true for pharmaceuticals companies in several cities in Ireland, flat-panel display companies in Osaka, Japan, and chemical companies in Rheinhessen-Pfalz, Germany. It has also occurred to a smaller extent in some emerging markets, with several auto manufacturers carrying out R&D in Sao Paulo, Brazil, and even more auto firms carrying out electric vehicle R&D in several cities in China, as well as many software companies carrying out research in Bangalore, India.

In addition to the three main country-specific drivers of MNE decisions to locate R&D in emerging markets – or overseas in general – we would expect greater R&D to take place where an MNE has a greater local presence. That is, when the firm has a greater amount of local activity, it probably will do more local R&D than in locations where less production, distribution and/or other corporate activity is located.

Hypothesis 4: *R&D activity by MNE affiliates will be greater wherever the MNE has a larger local presence.*

MNEs will be more likely to use their operations in emerging markets to carry out local R&D when those operations are more important to the firm. That importance may be due to a large local market or to a concentration of production or assembly by the MNE to take advantage of low costs in the emerging market in question (see e.g. Jha et al. 2018).

Each of these motives may exist by itself or in combination in a particular location. Our empirical analysis explores these four hypotheses.

5. Empirical evidence on factors contributing to the MNE decision for overseas R&D activity

5.1. Aggregate measures of MNE R&D in foreign affiliates

In most emerging markets the relatively low level of R&D activity by MNEs as well as local firms, presumably results from some country-specific factors that combine to deter such activity. An analysis of overseas R&D activity by United States multinationals for which detailed data are available may shed some light on this issue. Using data recently collected and provided by the United States

Department of Commerce, we can create a model of overseas R&D activity for the years 2004–2015.

The model was constructed with the data on United States companies and with data on country characteristics including market size, local cost conditions and local R&D activity, as well as control variables for openness, infrastructure quality, education levels and corruption. Data were not available for individual MNE sales or R&D activity, so those issues had to be explored at the aggregate level. The basic model that was considered was as follows:

$$\text{MNE R\&D}_{\text{country } i} = f\,(\text{GDP; labour costs; national R\&D; US MNE sales/GDP; openness; infrastructure quality; country education ranking; corruption})$$

This model is based on the expectation that R&D activity by United States MNEs depends on the national market size (+), local labour costs (-), the level of overall R&D activity in the country (+) and the size of the firm's own business activity in that country(+), as baseline conditions. In addition, it was expected that measures of country attractiveness to foreign firms in general would affect R&D activity by those firms, so the degrees of economic openness, infrastructure quality, education level and corruption were included in the attempt to model this R&D. As shown in the correlation matrix in the appendix, several of the "country attractiveness" variables were highly correlated, and so models were run using them alternatively. Also, data availability constraints caused a number of models to lose large quantities of observations, so the available sample was greatly reduced in those cases.

Table 4a shows that the variation in R&D activity by United States MNEs in 48 countries (both emerging markets and developed countries) was best explained by three or four factors. Outcomes were fairly similar across the six specifications, with the country's GDP and the amount of United States MNE sales in that country, along with overall R&D in that country, generally appearing as significant positive contributors to explaining the variation in R&D by United States-based MNEs. Interestingly, the local labour cost was *positively* associated with greater R&D activity in the total set of countries, though only significant in two of the specifications.[10] Among the attractiveness variables, it turned out that economic openness was not highly correlated with the other variables and could be run simultaneously with them. The only infrastructure variable to prove significant was the World Bank's

[10] The finding of higher wages being associated with more overseas R&D in MNEs is consistent with Lewin et al. (2009), who argued that restrictions on foreign scientists and engineers coming to the United States has promoted offshoring of R&D to find those skilled people elsewhere, often in high-wage Western Europe or Japan.

human development index, associated positively with R&D activity. The best models are presented in table 4a. Model 3 produced the most significant results, and all of the models explained about two-thirds of R&D activity by United States MNE affiliates worldwide.

Table 4a. Regression results, US MNE R&D activities in 48 countries

Variable/model	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
GDP	.0001***	.0002***	.0003***	.0002*	.0006***	
United States MNE sales	.0006***	.003***	.004***	.004***		.006***
R&D/GDP	422.8***	236.2**	305.3**	366.9***	335.2***	544.4***
Hourly compensation	3.438	9.104	11.37*	0.452	13.16**	8.03
Openness	9.051			8.40	7.52	9.07
Ease of starting business		-1.025				
Human development			2341**			1804
Government spending on education				4.87		
Corruption	-3.95	-5.68	-73.04	15.44	-44.97	-92.16
Constant	-1044**	-300.2	-2282**	-1040*	-691.4	-2499**
Adj R^2	0.678	0.686	0.682	0.668	0.439	0.660
Number of observations	265	275	223	219	305	215

Note: * significant at .10 level / ** significant at .05 level / *** significant at .01 level.

Table 4b. Regression results, United States MNE R&D activities in 22 emerging markets, 2004–2015

Variable/model	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
GDP	.0005***	.0004***	.0005***	.0004***	.0005***	
United States MNE sales	.00004	.00005	.0005	-.0005		.004***
R&D/GDP	109.9*	81.15*	43.95	179.31***	132.2***	69.83
Hourly compensation	-9.72**	-4.24	-5.00	-10.18***	-11.03***	5.35
Openness	-6.43**			-5.89***	-7.83***	-3.66
Ease of starting business		-1.288				
Human development			-25.45			206.3
Government spending on education				16.47		
Corruption	9.35	0.468	-5.88	-1.87	15.04	14.53
Constant	241.6	-47.92	-67.05	172.4	303.42	-165.9
Adj R^2	0.909	0.915	0.902	0.969	0.905	0.675
Number of observations	73	73	60	53	73	60

Note: * significant at .10 level / ** significant at .05 level / *** significant at .01 level.

Looking just at the 22 emerging markets in the overall sample, table 4b shows that market size and overall R&D activity remained significant, while local sales by the MNEs was significant only when presented without GDP in the model. The local cost conditions showed a negative and significant correlation with R&D activity by the United States MNEs in most of the specifications, as expected. For these emerging-markets models, GDP and local MNE sales were very highly correlated, and so model 5 presents the most conclusive results. These results are consistent with hypothesis 1 (market size), hypothesis 2 (low-cost personnel availability) and hypothesis 3 (overall R&D activity in the country). Hypothesis 4 – that MNEs should do more R&D where they have a greater local presence – was not supported, though this may be due to the fact that our measure was aggregated across all firms and not specific to individual ones. Unfortunately, many observations were lost due to missing data for the various indicators. Even so, more than 90 per cent of the variation in R&D activity by MNEs was explained by the models.

The findings in this aggregate-level analysis of R&D by MNE affiliates overseas are consistent with the literature on two of the key drivers of such activity. There was greater R&D in affiliates where the local market was larger and where a greater level of R&D existed in the local economy overall. Results were different for emerging-market affiliates versus developed-country affiliates with respect to the cost of local employees: emerging-market affiliates carried out more R&D in countries with lower labour costs, while in developed-country affiliates greater R&D took place where labour costs (and presumably skills) were higher.

Although the quantitative evidence presented here is useful for understanding some of the probable motivations for MNEs to put R&D activity in emerging markets, it would be additionally valuable to know whether these factors really are recognized by company decision makers in their choices on such activity. The next subsection looks at half a dozen cases of MNE affiliates carrying out R&D activity in Asia, Latin America and Africa. These examples are based on discussions with decision makers in most of the companies and use secondary sources as well.

5.2. Company-specific examples

Despite the various indicators of R&D activity in emerging markets that were presented above, there still is not a completely clear picture of this phenomenon at the corporate level. That is, we do not know how much of the R&D that an MNE carries out in a country is related to product and how much to process, whether the R&D is very much the development type or is more "upstream" applied research, or other details about the precise activities involved. This section therefore adds some detail about the characteristics of R&D, on the basis of a variety of company experiences. The evidence presented here is divided into the manufacturing and the services sector, to give an idea of the scope of R&D by MNEs in several emerging markets and also to demonstrate some of the most noteworthy ventures of this kind in emerging markets.

5.2.1. Manufacturing

Volkswagen in China

The Chinese auto industry has evolved from a monopoly, tightly controlled by local government before the 1980s, in which First Automotive Works (FAW) began producing the Jiefang CA-30 passenger car in Changchun (Jilin Province) in 1956 and the Nanjing auto works started producing a truck model in 1958. Other local auto manufacturers were set up in Shanghai and Beijing during the period of tightest government control of the economy. At no point during that period were more than 10,000 cars produced per year, and clients were almost exclusively government agencies and state-owned companies, such as taxi service providers.

In the mid-1980s, the Government decided to allow the importation of greater numbers of cars, mainly for use as taxis for the state-owned taxi companies in Beijing and Shanghai. Volkswagen and, subsequently, other foreign automakers were allowed to form joint ventures with a state-owned Chinese partner as long as foreign ownership was limited to a 50 per cent share in the joint ventures. The Government's intent was to rapidly develop a car industry, learning from the foreign companies how to make cars while maintaining control of the car industry. Volkswagen in 1984 signed an agreement with the city of Shanghai to produce cars locally in a joint venture, which initially was used primarily to assemble vehicles from imported kits.

When a greater degree of economic opening began in the early 1990s, the national Government authorized more foreign auto manufacturers to enter China, and more vehicles to be sold. Volkswagen was the clear market leader, operating through its joint ventures with Shanghai Automotive Industrial Corporation (SAIC) as well as with FAW in Changchun. The market grew quite dramatically, and by 2010 the Volkswagen joint ventures were producing over one million cars per year in China.

Volkswagen began significant R&D activity in China with its R&D centre in Shanghai, launched with SAIC in 1996. Over the years, more research work was pursued in the joint ventures involving SAIC and FAW, largely for cars sold locally. Then in 2016 VW announced the establishment of its "Future Center Asia" in Beijing. This R&D centre is developing a range of automotive technology for use globally, including the key electric vehicle technology that is so important in China today. During the launch, the research centre noted specifically that it would focus on autonomous cars and on digitalization of systems used in its vehicles. According to Jochem

Heizmann, the head of VW China, “We view China as an incubator for innovation and new technologies and as a source of solutions that can be transferred to the world. In China, the future is now.”[11]

Motorola in Brazil

Motorola began R&D work at its Jaguariuna (Campinas) plant, established in 1997. Two teams of technical staff work at the facility. The Global Software Development group of about 150 Motorola staff and nearly 300 people from partner firms and institutions develops new cell phone applications for use worldwide. The regional engineering development group of about 70 Motorola staff and several dozen people from partner institutions works on process improvement and adaptation for cell phones made and sold in Latin America.[12]

Government incentives have played an important role in attracting this innovative activity to Brazil. The company faces a 70 per cent tax rate on earnings from imported cell phones and other products sold in Brazil. A 40 per cent tax exemption is offered for cell phones produced locally in Brazil, and of that amount, 5 per cent must be spent on local R&D activity.[13] This tax incentive policy has attracted not only Motorola but several other electronics or telecommunication firms such as Siemens, Nokia and Samsung to undertake R&D activity in Brazil. It appears that the incentive policy was able to stimulate an initial R&D commitment from Motorola, but that subsequent expansion in this activity has been undertaken strictly on a business basis (that is, on the basis of the effectiveness and cost of doing the work in Brazil versus doing it in other affiliates of Motorola worldwide).

In 2015 Motorola announced that it had doubled the number of research staff at Jaguariuna, with the 200 additional people working on industrial design, user interface, research, engineering and prototyping, and packaging and web applications. Motorola designated the Brazilian operation as a global product development hub and has been using the added research for applications worldwide. The R&D focuses on 4G technology but also includes cloud computing and big data research. Since 2011 Motorola’s cell phone division has been operated

[11] See https://www.volkswagen-media-services.com/en/detailpage/-/detail/New-Future-Center-Asia-to-be-built-in-Beijing/view/3435338/2d19f59bce927f8109b985a499255eb?p_p_auth=DE4YxeQY.

[12] In 1997, Motorola decided to open a semiconductor design centre in Jaguariuna. This group started with key people from the semiconductor industry in Brazil. Today this group employs more than 100 experts in semiconductor design. In early 2005, Motorola decided to spin off its semiconductor operations and created Freescale, which continues to invest in this R&D team.

[13] In force since 1993, the Informatics Law (law 8.248/91, altered by law 10.664/03) reduces the industrialized products tax (IPI). On the other hand, beneficiary firms have to invest 5 per cent of their total net sales in R&D activities (at least 2.3 per cent of which must be invested in cooperation with universities and/or research institutes). The amount also includes the contribution to the Sectoral Fund for Informatics (CTINFO).

as a subsidiary of another company: Google purchased it at that time and then sold the division to Lenovo in 2014.

Continental AG in Queretaro, Mexico

The German tyre and auto parts manufacturer, Continental AG, began production of tyres and parts in Mexico in the 1970s, with plants in Mexico City and San Luis Potosi. Over the years Continental has set up additional manufacturing and now operates 19 plants across the country. The firm's overall product line in Mexico ranges from high-quality surface materials for vehicle interiors, brake systems and turbochargers to instrumentation and control units and chassis control systems for cars, trucks and specialist vehicles. R&D facilities were set up in two of these facilities, with local mandates to support the development of auto parts for the Mexican market and the market in the United States for Mexican-assembled vehicles. Beyond car parts, Continental-Mexico also manufactures conveyor belts for handling bulk goods and industrial hoses for use in the petroleum industry as well as in the cosmetics and food industries.

In 2018 Continental announced the opening of a new research facility in Queretaro (near Mexico City), for R&D on electronic auto parts and on tyres, particularly as related to autonomous vehicles. At the outset in 2018 the R&D facility employed 160 engineers, with plans to expand the group to over 1,000 scientists and engineers within four years. The original two R&D facilities employed more than 1,700 scientists and engineers by 2018 (in a total Mexican workforce of about 24,000 people). The research centres focus on the development of components such as fuel injection control units, infotainment and connectivity solutions, airbags and systems for access control, and vehicle safety and security. Continental-Mexico's research efforts have thus far resulted in 23 patents, 126 patent applications and 837 invention disclosures.

Continental is using its new Mexican research facility for worldwide application of the technology involved in driverless vehicles. This is actually not wholly different from the existing applications of Continental's R&D in Mexico, since the target clients continue to be global auto manufacturers who assemble vehicles in Mexico for sale in the United States and elsewhere.

Intel in Costa Rica

Intel Corporation, the world's leading microprocessor chipmaker, completed a chip assembly and test facility in Costa Rica in 1998. Over the first ten years since start-up, total investment has been estimated at close to half a billion dollars, mainly allocated to the build-up and operation of two major high-volume production facilities and their support infrastructure. By 2014 Intel employed about 2,500 professionals and technicians at this facility. Their main task was to assemble the company's Xeon, Pentium and later lines of microprocessors for servers and personal computers, as well as chipsets. Intel's first shipment from the Costa Rica facility occurred in April 1998.

Intel's investment in Costa Rica in 1998 was the largest ever made in the country. The cost of constructing the three factory buildings alone represented at that time more than the total amount of FDI that the country typically received annually. Between 1990 and 1996, incoming FDI averaged $272 million per year. By 2010, exports from the Intel plants represented 15 to 20 per cent of overall country exports, at about $8 billion, and overall annual FDI had risen to an average of $500 million. The challenge of putting such a major investment into such a small country was clearly seen in 2014, when Intel closed the manufacturing operation and relocated that work to its other United States and international facilities. Only the chip testing facility was retained, along with about 1,000 of the employees.

Intel's FDI in Costa Rica was an exception to the traditional MNE investment in Latin America, because this FDI was in a high-tech sector in which firms usually have imported into the region from the United States, the EU or Japan. The amount of R&D done at the facility was limited, since the work was primarily used for final chip assembly and quality testing. Nevertheless, Intel did do development work at the facility, and it appears that development work is continuing without the production presence in Costa Rica.

The operation in Costa Rica had three goals:

1. manufacturing and distribution of high-quality, low-defect chips and chipsets;
2. process and product engineering development and quality control; and
3. shared services: support services for multiple Intel locations in the region, such as a call centre, software development, regional back-office support, microprocessor design and accounting services.

In manufacturing, the main activity that relates to R&D was the quality control effort to ensure high-quality chip production. Intel did not consider this to be R&D, though work was done to incrementally improve the production process. In "back-end engineering" 60 to 80 people were involved in product development, which mainly implied work to improve the chips being manufactured. In addition, another 100 people (although some of their number overlapped with the previous category) were involved in software development related to the chip production process.

"Shared services" is similar to work carried out by many MNEs in offshore locations to lower the cost of call centre and back-office business services such as accounting. Intel carries out these two functions at the Costa Rica facility and may identify additional services for the company that could be provided globally or regionally from Costa Rica. When the manufacturing operation was shut down in

2014, only the chip testing and related activities, along with back-office services, were retained, so Intel exports from Costa Rica dropped dramatically – though employment dropped by only somewhat more than half.

5.2.2. Services

Software development by IBM in India

Another MNE research activity that is visible in recent years in India is the development of English-language software by firms taking advantage of India's highly skilled and lower-salaried technical personnel. IBM has established a major research centre there, jointly in Bangalore and New Delhi. This United States-based MNE does a range of IT research in its Indian lab, which was founded in 1998. Its goals are mainly to develop applications for clients in financial services, telecommunications, and health care.

The focus of IBM's efforts is in big data analytics, machine learning and software engineering. In 2018 the group had four major research teams. According to the company, "The Cognitive Solutions and Services department at IBM Research – India is focused on developing the next generation of cognitive technology solutions and services to fundamentally change the way we interact with computers, people, and enterprise scale systems." The Analytics and Optimization team was focused on a number of human resources-related projects, including ones aimed at optimal recruiting of talent, a skills-based internal organizational structure for classifying employees, and a talent management system. The Blockchain and Smart Contracts team aims to develop solutions for their international trade and supply-chain clients who need secure and decentralized information systems for their contracts and inventory management, among other applications. And finally, the Information and Analytics team focuses on cloud computing, data mining and big data management. All of these areas are intended to have global applications of their R&D, though projects tend to be assigned on the basis of local client needs.[14]

R&D by Apple in China

Apple encountered a string of setbacks in China during the 2010s, ranging from market share incursions by government-supported local competitors Huawei and Xiaomi, to demands for the company to stop providing access to its online music and book services (because they violated Chinese media rules), to problems with an iPhone battery. These setbacks were clearly a challenge to Apple, since China is its second-largest market after the United States and will continue to be a major

[14] For background on IBM's R&D in India, see http://www.research.ibm.com/labs/india/.

source of revenue in the future. Much of the assembly of Apple iPhones is done by Foxconn in China as well, although this could change with the possibility of moving assembly to lower-cost countries in the future. In short, China is vital to Apple as a market, as a key point in Apple's supply chain, and as the source of current and future strong, government-backed competition.[15]

In 2016 Apple announced its intent to set up an R&D centre in Beijing the following year. By early 2017 this commitment had blossomed into plans for four R&D centres in China: in Beijing, Shanghai, Shenzhen and Suzhou. Apple committed more than $500 million to this program, which will put several thousand Chinese engineers and scientists to work on next-generation Apple projects. Although the company has not identified the specific assignments of the new research centres, one very likely target will be autonomous car technology. Apple bought the Chinese ride-sharing service Didi Chuxing in 2017 and later also acquired Uber's business in China.

This venture or set of ventures marks an interesting step for Apple, whose key rivals include the Chinese giants Huawei and Xiaomi, and whose interest in the huge Chinese market is central to future sales. Yet at the same time as Apple seeks to build its business there, the Chinese Government explicitly supports local firms in high-tech industries such as telephones and software, and blocks foreign firms from building market share and from selling a wide array of products and services viewed as undesirable or threatening to the Government's interests. Apple has stated its interest in hiring the best Chinese minds to work in its research teams, so the stage is set for some very interesting confrontations in the future.

Adobe's R&D hub in India

Software giant Adobe, the producer of the Acrobat programs, has been operating in India for more than a decade and has established R&D centres in Bangalore and Noida (New Delhi). The company employs about 2,000 scientists and engineers in these research hubs, focusing on not just the two core products but also wide applications in machine learning, natural language processing, information retrieval, big data systems and image processing.

Rather than "tropicalizing" existing Adobe products and services from the United States, several Adobe products are today being developed in India. Adobe Illustrator is being completely designed there, as is Adobe Lightroom. Nearly 80 per cent of the further development of Adobe Acrobat is also being done in India. In 2018 Adobe

[15] An interesting aside is that Apple, like other United States-based MNEs, is finding it increasingly difficult to obtain visas for foreign nationals to come to work in its United States research labs. So, rather than losing these researchers, United States firms are moving some R&D overseas to where those people are, particularly concentrated in China and India.

announced that it would establish a new artificial intelligence lab in Hyderabad to support its work in innovation generally and cloud computing in particular. Overall the company states that one-third of its global R&D is done in India.

Adobe India's client focus is on small and medium-sized enterprises (SMEs), government and education. For SMEs, Adobe became involved with the industry associations for jewelry, ceramic tile and fashion. It then developed software for application in these small-end clients that would be overwhelmed by larger enterprise resource planning programs. The government sector was targeted for building a portal to connect with citizens and also for working with the national education system. As noted by Adobe's head of research in India, "Every interaction with government starts and ends with forms. Adobe has the most used document technology" (i.e. PDF [portable document format], with signature and other security and document management features).[16]

5.3. What are emerging-market MNEs doing for overseas R&D?

Although emerging-market MNEs and their overseas R&D activities are outside the scope of this analysis, they nonetheless deserve mention. Some emerging-market MNEs have moved directly into international R&D structures by acquiring firms with such networks in place. Good examples include Geely, which acquired the Swedish multinational auto firm Volvo, and Cemex, the Mexican cement company, which acquired the Australia-based Rinker. Additional examples include emerging-market companies that acquired Triad-based MNEs and then moved their own headquarters to locations such as London or New York (e.g., mining company Anglo American, which moved from South Africa to London, and Anheuser-Busch InBev, which involved the acquisition of the Belgian brewer Interbrew by the Brazilian brewer Ambev, followed by the acquisition of United States-based Anheuser Busch). In each of these cases the move to overseas R&D came largely or completely from the acquired firm's portfolio of activities. The international expansion of R&D by emerging-market MNEs deserves a separate treatment, and it is not pursued further here.

[16] See https://www.business-standard.com/article/companies/india-significant-player-in-adobe-s-transformation-journey-115061500953_1.html.

6. Conclusions and policy implications

R&D activities of multinationals have extensively moved outside home countries in the past two to three decades. Some of these activities have moved to emerging markets, most often to China or to India. Fairly limited development work for the adaptation of products and services to local conditions is quite common across many emerging markets. Very little R&D is pursued in Latin American and African countries. There are exceptions, such as the auto R&D activities of General Motors, Ford and Toyota in Brazil, and some limited activity such as in mining in South Africa. In Asia (other than China and India) there is similarly a very low level of R&D activity in the affiliates of multinational firms operating there. And this R&D tends to be the most applied (development), least sophisticated activity, used mostly for the adaptation of products and services to local market needs and characteristics. This relatively low level of R&D by MNEs is consistent with overall measures of R&D activity in Latin America, Africa and the smaller countries in Asia, which also trail the other regions noted above.

China and India are clearly the exceptions to this rule. Innovation activity by foreign MNEs has skyrocketed in China, where United States-based firms do more offshore R&D than elsewhere in the world today, except for a handful of EU countries and Canada. India has also attracted a very large amount of R&D by foreign MNEs, also ranking above most other countries outside of the EU and Canada. In China's case much of the R&D has been forced by government policies, whereas in India the MNEs have chosen to take advantage of opportunities there in a very large market with large numbers of relatively low-cost, skilled scientists, engineers and business analysts.

Although companies still tend to carry out R&D in emerging markets for application locally, there is a growing trend to source some activity there for the global market. Continental uses its Mexican R&D facilities to develop auto parts for autonomous vehicles that serve global clients who mainly have their production in Mexico too, where they can use the innovations first. Adobe is using its Indian R&D facilities to do most of the development of new features of Adobe Acrobat, as well as a number of artificial intelligence projects, with application to the company's global market. Apple is clearly targeting the global market for its R&D on autonomous vehicles in China – though the initial application is very local to its recently partially-acquired company, the ride-sharing service Didi, which also bought Uber's local subsidiary. This could be called reverse innovation, since the new technology is transferred to more developed countries later. Interestingly, China is the world's largest auto market, so first carrying out R&D there makes sense for auto companies, auto parts companies, autonomous vehicle companies, electric vehicle companies, and the like.

If emerging-market governments do wish to attract more R&D activity, then our regression results provide some guidance on what they might do. Although it is not possible for a country to become a much larger market, the existing large markets in China, India and Brazil are attracting a growing amount of MNE R&D. In addition, alliances of smaller emerging markets could form customs unions or free trade areas that form a more-or-less single market. If Latin American, Asian or African countries could form functioning customs unions that really do permit free trade among members, this could create the bigger markets that attract MNE innovation activity.

It also appears that these countries could aim R&D-attracting policies at the negative factors that dissuade companies from investing. Such policies could include an increase in the level of education of workers, or more specifically an increase in the national level of R&D activity carried out by companies, government and universities. Government policies that stimulate the education of scientists and engineers can contribute to attracting the R&D activities of MNEs, though it must be recognized that small markets still may not succeed in this effort because of their small numbers of available technically skilled people. Even so, the case of Costa Rica's policy to attract Intel shows that even a small country may be able to attract MNE R&D activity, which in turn may produce additional investment and R&D by other multinationals in the same or related products and services. The Intel case is the most striking example of a tremendously successful public policy that attracted the company, generated thousands of direct jobs, and built up skills and ancillary businesses in a tiny country (population 4.9 million). Intel mostly used the facility to take processor chips out of wafers produced elsewhere, test the chips, and then ship them to target markets around the world. This investment lasted for more than 17 years – and when Intel decided to consolidate the chip processing elsewhere, they still retained half of the employees in Costa Rica in back-office processing as well as dozens of local and foreign companies doing tech-related activities.

Policies to attract R&D for local market adaptation (the "tropicalization" of products and processes) might seem unimportant. However, the examples cited in interviews and described above show that MNEs move from that adaptation activity into global or at least regional product and process development. Once a base is established, multiple examples show that MNEs do tend to move toward a greater commitment to broadly applicable R&D in their emerging market affiliates. The Brazilian tax incentive policy that reduces taxes for firms that manufacture locally if they spend a percentage of that tax savings on local R&D appears to have worked quite well in the information and communication technology (ICT) and automotive industries.[17]

[17] This policy may be a compelling one for MNE managers, since the environment offered by Costa Rica to attract Intel was largely based on tax incentives – and the Intel investment brought with it a nascent R&D activity in that country. Even so, it must be explored in more detail to ensure that the tax incentive policy really does have generalizable applicability, or if it really only works easily in a large country such as Brazil, and that Costa Rica's dealings with Intel were not just an exception. Still, the policy is very important to explore in detail, because it could be a tool that enables smaller countries to build their attractiveness to MNEs for innovative activities.

These last statements raise a prior question: what roles do MNEs play in emerging markets in R&D and innovation? If the firms were not too heavily involved in the innovative activity in a country, then an expansion of their commitment would generally be helpful. In fact we know that companies carry out a much smaller percentage of R&D activity in most emerging markets (less than one-third of total R&D spending) than in the industrial countries (over two-thirds in the United States). Governments are responsible for most of the rest of R&D spending in emerging markets.[18] One cannot conclude that MNEs are the leading sources of R&D in emerging markets, though they do tend to possess leading-edge technology. For economic development, and to build emerging markets as sources of innovation globally, mechanisms should be developed to entice both foreign MNEs and local firms to undertake more path-breaking R&D activities. This paper focused on the MNEs, and by examining their activities, it may suggest some ways to pursue the development of greater innovative activity in emerging markets.

Future research could pursue the question of what innovation activities emerging markets might attract. A more detailed exploration of this phenomenon could produce lessons that would be applicable more widely. And, of course, additional examination of the policy tools that are used and could be used by governments to attract R&D and other innovation would be very valuable. Tax incentives for R&D activity are clearly one policy that has worked. Many other policies could be considered, from incentives to attract scientists and engineers to do local research, to penalties for importing R&D rather than carrying it out locally. The idea of using free trade zones for R&D activity could be feasible in business hubs such as Singapore, Dubai and Panama. On the business strategy side, it would be useful to look again at which innovation activities MNEs are placing in emerging markets, and how these activities can be utilized to build the competitiveness of the firms globally.

[18] R&D is a substantial and growing enterprise in the United States. All in all, the United States invested an estimated $510 billion in R&D in 2016. This represents about 2.7 per cent of the country's GDP. The largest share of this money (about 72 per cent) came from industrial firms. Most of the balance (22 per cent) came from the federal, state and local governments. Colleges and universities, private foundations, other nonprofit institutions, and state and local governments provided the remainder. See National Science Foundation, *InfoBrief* (December 2017). NSF 18-306, https://www.nsf.gov/statistics/2018/nsf18306/, and NSF, "National Patterns of R&D Resources", https://www.nsf.gov/statistics/2018/nsf18309/.

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Appendix A. Correlation matrix of factors related to R&D by United States MNEs

	RDUSMOFA	GDP	United States MNE sales	R&D/GDP	Openness	Hourly compensation	Human development	Corruption	Ease of starting business
All economies									
RDUSMOFA	1.0000								
GDP	0.5535	1.0000							
United States MNE sales	0.7958	0.5692	1.0000						
R&D/GDP	0.3656	0.2481	0.2142	1.0000					
Openness	0.2311	-0.0621	0.3147	0.2645	1.0000				
Hourly compensation	0.3677	0.1723	0.3070	0.4927	0.3697	1.0000			
Human development	0.2614	0.0188	0.2788	0.5596	0.4956	0.5935	1.0000		
Corruption	0.1962	0.0261	0.3584	0.3250	0.2067	0.1582	0.4813	1.0000	
Ease of starting business	0.1942	-0.0364	0.2971	0.3717	0.5725	0.5089	0.5071	0.2478	1.0000
22 emerging markets only									
RDUSMOFA	1.0000								
GDP	0.7838	1.0000							
United States MNE sales	0.7169	0.8125	1.0000						
R&D/GDP	0.4895	0.5560	0.4130	1.0000					
Openness	-0.1137	-0.1576	0.0456	-0.1087	1.0000				
Hourly compensation	0.1344	0.0775	-0.0235	0.4857	-0.1404	1.0000			
Human development	-0.2483	-0.1272	-0.0895	0.1522	0.1911	0.4370	1.0000		
Corruption	-0.0352	0.0234	-0.0334	-0.0056	0.1911	0.0189	0.1876	1.0000	
Ease of starting business	-0.1696	-0.0595	0.0493	0.0710	0.4462	0.1514	0.1984	0.2209	1.0000