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G20: A Room for Global Club Governance: Towards a Global Innovation System?

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G20: A Room for Global Club Governance: Towards a Global Innovation System?[1]

Erkan Erdil[2]**, Dirk Meissner**[3] **and Özgür Kadir Özer**[4]

I. Introduction

In the new digital transformation age, innovation processes is genuinely becoming more complex. Most of the hi-tech or medium-tech products and services are produced at different locations with rising collaborations. The radical changes observed in the last decades make the innovation processes and innovation system concepts as being a transnational issue rather than limited with the national borders. This does not mean that the classical concepts of national, regional, sectoral or technological innovation systems are useless but it calls for an action for the entangled relations among these systems through club governance. G20 is observed as a significant economic playground with its connections through east to west and north to south of the globe. This stylized fact underlines the changing geography of innovation. As an early attempt to conceptualize global innovation systems (GIS), Dahlman (2012)[5] defines 8 dimensions where global networks cutting across national innovation system (NIS), namely trade in goods and services; activities of multinational companies; activities of other international organizations (international agencies and NGOs); global research networks; global information and communication networks; global diaspora networks; global flow of people (travel, international consultancy, immigration) and global education network. This paper concentrates on some of these dimensions such as knowledge flows inside G20 for designing an effective club governance to serve for a better world. Brown and Levy (2015) label Global Innovation System (GIS) as the new phase of capitalism where its certain features are reflected in already existing NIS though it surpasses the roots of NIS. GIS functions as integrating tool for a sound global structure of innovation activities. It further defines new global division of labor which is more complicated than present production and value chains. Such an attempt necessities a new design of global knowledge pipelines and local buzz in a more densely manner. This structural design needs policy intervention at global level through clubs like G20. Binz and Truffer (2017) based on present innovation concepts remodel a "multi-scalar" conceptualization of GIS. They identify two mechanisms in this attempt namely generation of resources in multi-locational subsystems and the establishment of structural couplings among them in GIS. Binz and Truffer (2017) offers a taxonomy

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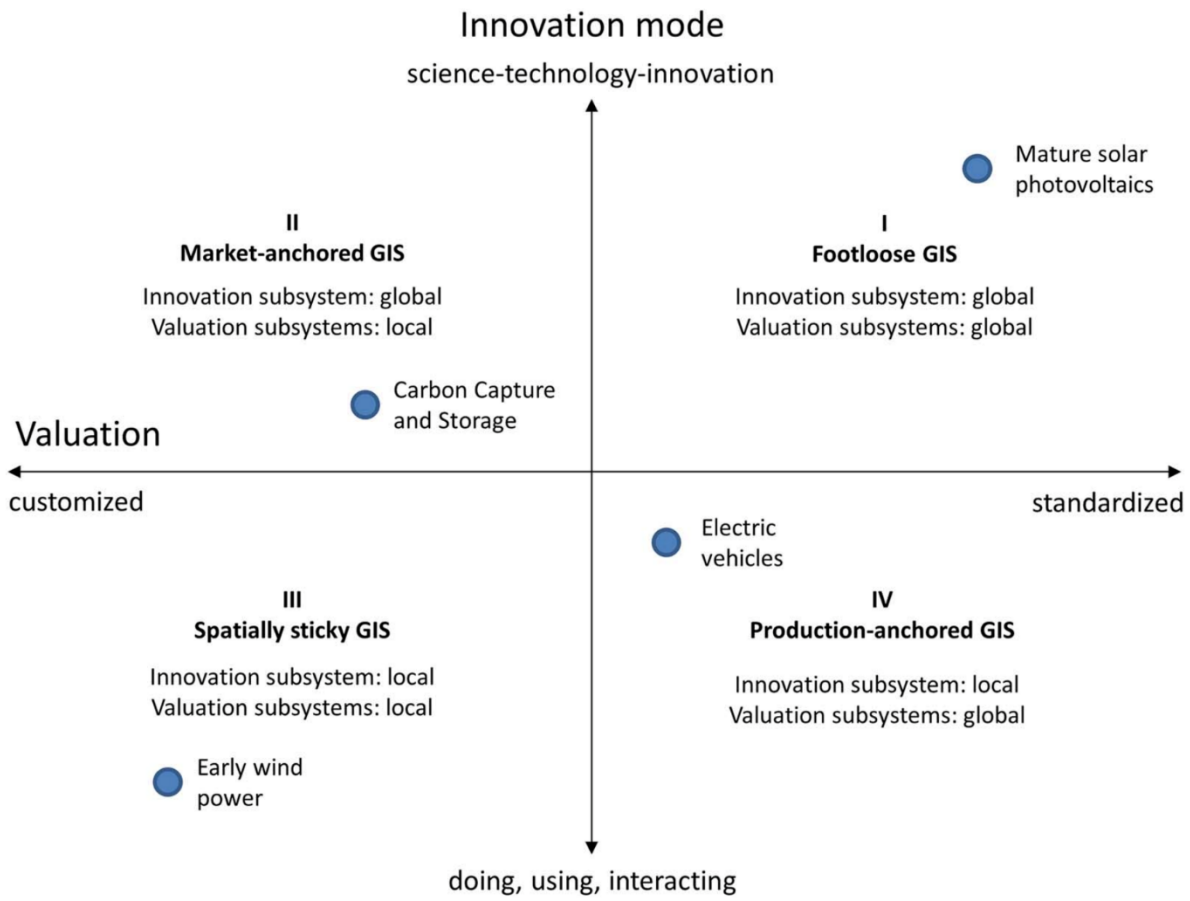
[5] https://www.oecd.org/innovation/inno/49433772.pdf

on 4 generic GIS configurations as can be seen from Figure 1 which is the most comprehensive effort to understand GIS in the literature.

Figure 1: A taxonomy of GIS in clean-tech industries



Source: Binz and Truffer (2017)

It's postulated by the authors that such an approach is instrumental for policy intervention to mitigate increasing spatial complexity in innovative activities. In fact, what is proposed by Binz and Truffer (2017) seems to be a global technological innovation system which we can be labeled as GTIS. The taxonomy may be at work for different global technological systems yet the main features and policy-making rationale will be significantly variable in different systems.

This paper develops a theoretical and conceptual framework for the global governance of STI policies and then use secondary data to determine the existing situation towards modelling the global innovation system. We define GIS as a *globally governed network of collaborative relations between different actors, including firms engaged in updating knowledge base towards any type of innovation.* Currently global governance is mainly affiliated with working parties and committees attached to international organizations and serve as platforms for information and idea exchange between

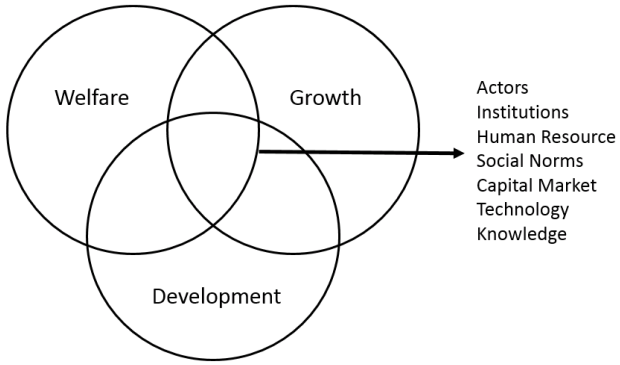
countries. Such working groups frequently involve numerous national experts representing countries and operated by secretariats. The empirical part of the paper focuses on STI competence of G20 countries and their interlinkages with the other clubs through knowledge generation and spillovers. The last part of the paper will focus on the construction of an implementing model and policy discussions. The main target of the paper will be to answer whether a global governance system of STI policies in the context of G20 is possible or in other words, whether a global GIS can be managed by G20 as a significant club of economic governance.

II. Global Social Welfare, Knowledge Generation and Club Governance

The literature on welfare in evolutionary economics mainly focuses on fostering education and innovation as a central means of welfare and growth. In this perspective, it is considered that the transformation and development of societies is *strongly* depended upon the technological development or the emergence of technological routines. This transformation requires knowledge generation. However, one may argue that this strong emphasis on innovation and technology only represents a fragment of an evolutionary welfare economics. Nevertheless, some additional arguments and theories related to other dimensions of economic welfare might highlight the importance of the need for a proper analysis of knowledge creation in societies. In this context, it can also be argued that suggesting a concise concept of evolutionary welfare is a necessary condition for the development of an evolutionary welfare framework.

Supposedly, the evolutionary welfare framework, presented in Figure 2, points out that growth and development has a bidirectional causality and thus, a concurrent feedback. Moreover, current approaches suffer from a vague or limited applied research to determine the *real* strength of welfare economies. Of course, we are challenging a neoclassical welfare or purely Keynesian welfare; but the locus of our research is *implicitly* founded on the theory of evolutionary welfare including gradual improvements of *all* capital infrastructures including actors, institutions, human capital and relational capital through collaboration networks in the context of economics of technology. From this perspective; as one of the most important features for welfare economics; we propose that the knowledge generation through linkages, collaboration, etc. should further be analysed. In addition, we further propose that the specific analysis for knowledge generation should be accomplished for emerging economies that encounter infrastructural problems or problems at various levels of innovation systems (national, regional, sectoral, technological); but having *relative* advantages in terms of relational capital and technology transfer as well.

Figure 2: The evolutionary welfare framework

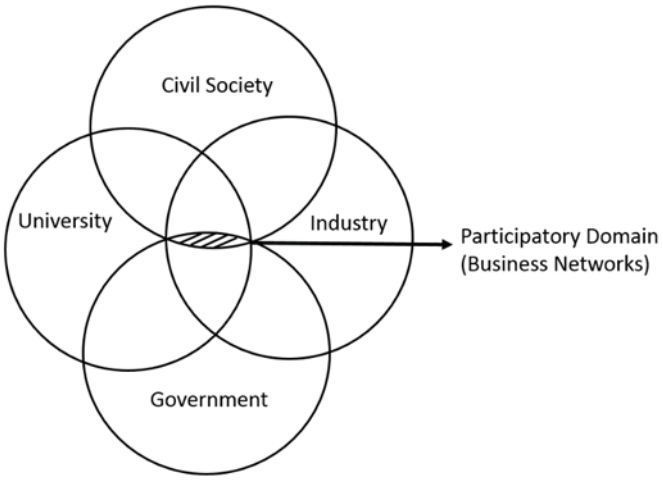


Source: Göksidanet al (2018)

Closing the gap or *catch-up* terminologies relate to the ability of a single country to narrow the gap in economic aspects (productivity and income) and technology (as an intermediary) with a leader country in order to reduce the overall differences as a whole. The issue of catch-up has been crucial for the academic research as growth proceeds such convergence on the long run (Solow, 1974). Of course, it is highly metaphorical that all developing countries tend to converge and succeed in catching-up while others fall behind (Abramovitz, 1986).

On the following, engaging a wide range of actors has long been fundamental to economic development, the significance of and the need for a new approach has emerged: the Quadruple Helix model by proposing to add a fourth group (civil society as innovation users) to a classical Triple Helix model. This model is potentially "open" to support economic development since these different actors have skills and knowledge. Furthermore, this model develops open innovation's dialect with a new development approach in that of innovations are pertinent for users who drive the innovation processes. In line with this perspective, new innovative products, services and solutions are developed with the involvement of users in their role as lead users, co-developers and co-creators (see Figure 3).

Figure 3: Quadruple Helix Model



Source: Göksidan et al (2018))

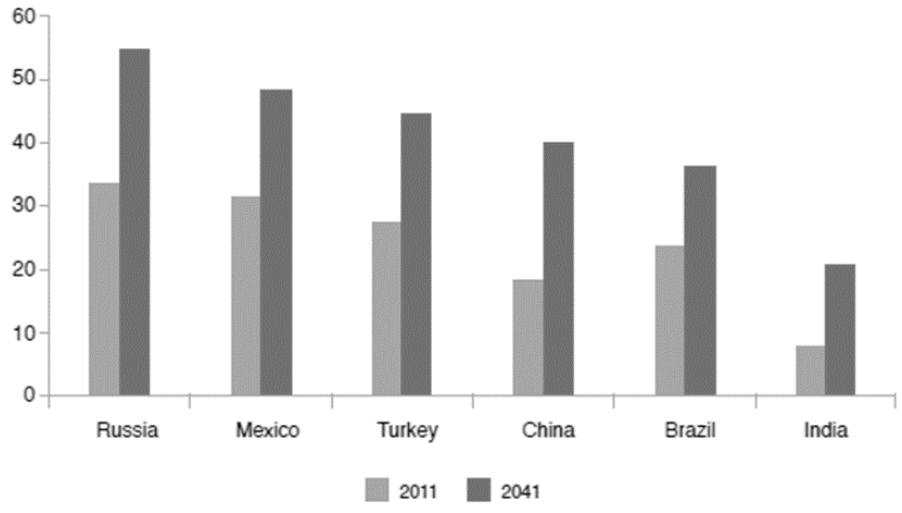
The divergent economic performance of developing countries as related knowledge generation may also be characterized by convergence in productivity and income and GDP per capita compared to the industrialized economies (as the most striking evidence on the great variation of performance between countries). However, the efforts for catching-up cannot be solely explained by higher growth in GDP per capita. For instance, according to a financial report by PWC (2012), Turkey, *as an emerging economy*, is expected to perform a lower GDP growth as compared to Brazil (with a *fragile* economy). In this report, Turkey is ranked 16th in the world as GDP per PPP in 2011 and expected to be ranked 12th in year 2041 (see Table 1 and Figure 4). On the contrary, Brazil sustains its relative economic and geographic advantages by sustaining a bigger GDP growth as ranked 7th to 4th in 2041. Nevertheless, current scientific evidence on economic growth (see IMF World Economic Outlook 2015) and innovativeness index (see The Global Innovation Index 2016 in Cornell University, INSEAD, and WIPO 2016) show us that Turkish rankings are preferably *stable* (ranked 42nd in 2016; was 58th in 2015). But, it can be argued that Turkey is showing relatively *low performance* when compared to other developing countries having higher income like Brazil (ranked 70th in 2016; was 69th in 2015; and Chile (ranked 44th in 2016; was 42nd in 2015). Further argument might be extended in such a manner that economic gap analysis restricted with average GDP growth and catching-up require *more* (analysis and policy development) than average growth in GDP with respect to the target levels of innovativeness growth.

Table 1 : Top 20 countries by GDP on a PPP basis (constant 2009 US$bn)

Rank	Country (FY2011)	Rank	Country (FY2041)
1	**US**	**1**	**China**
2	**China**	**2**	**US**
3	**India**	**3**	**India**
4	**Japan**	**4**	**Brazil**
5	**Germany**	**5**	**Japan**
6	**Russia**	**6**	**Russia**
7	**Brazil**	**7**	**Mexico**
8	**UK**	**8**	**Indonesia**
9	**France**	**9**	**Germany**
10	**Italy**	**10**	**UK**
11	**Mexico**	**11**	**France**
12	**Korea**	**12**	**Turkey**
13	Spain	13	Nigeria
14	**Canada**	**14**	**Korea**
15	**Indonesia**	**15**	**Italy**
16	**Turkey**	**16**	**Canada**
17	**Australia**	17	Vietnam
18	**Argentina**	**18**	**Saudi Arabia**
19	**Saudi Arabia**	19	Spain
20	**South Africa**	**20**	**Argentina**

Source: PwC Analysis Report 2012 (based on International Monetary Fund World Economic Outlook April 2012)

Figure 4: GDP per capita in PPP terms in 2011 and 2041 (constant 2009 US$ % of US GDP per capita)



Source: PWC Analysis Report 2012 (constructed with IMF WEO)

To analyse patterns of convergence and divergence related with knowledge generation capacities and capabilities, it is also necessary to assess organizational changes and economic development that influenced the accumulation of technological and social capabilities in catching-up countries. The role

of knowledge generation in catching-up at the country level experiences relatively shows us that the diversity of growth processes among developing countries reflects differences in institutional patterns in which social and technological capabilities have been accumulated through different interactions (see UNIDO 2005).

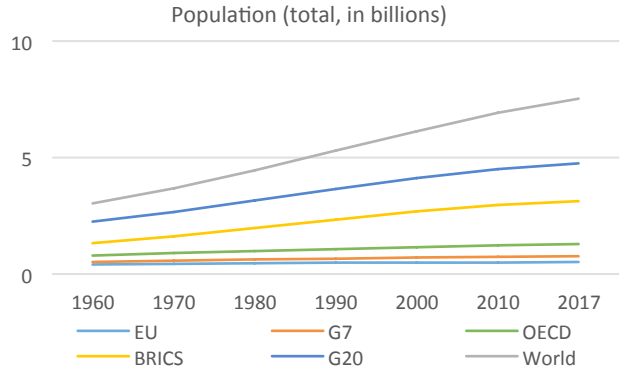
III. G20 in Numbers: Some Stylized Facts

In this section, first, the main socio-economic indicators of G20 economies are presented to compare their potential with other global and regional economic clubs. Then, data related to G20 economies' exports and FDI is summarized to picture the flows of goods and services from G20 economies. To capture the competence of G20 economies in STI, relevant data is presented at the end of the section.

III.1 Socioeconomic indicators

By 2017, G20 economies host 4.7 billion people – 63.2% of the world population (Figure 5). If we exclude China and India, that figure reduces to 27%. G7[6] countries are home to 10.1% of the world population, EU[7] countries are 6.8%, OECD members are 17.2%, and BRICS countries are 41.6%. G20 economies also house 66.5% (about 2.3 billion persons) of total labor force in 2017 (Figure 6).

Figure 5: Population change in major economic clubs (1960-2017)

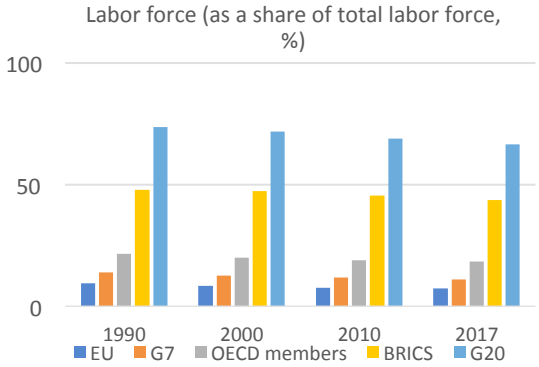


Source: World Development Indicators

[6] Canada, France, Germany, Italy, Japan, the United Kingdom (UK), and the United States (US).

[7] In this section EU-28 is meant by EU, and all figures about EU includes France, Germany, Italy, and United Kingdom unless indicated otherwise.

Figure 6: Change in the number of labor force change in major economic clubs (1990-2017)



Source: World Development Indicators

According to UNDP's Human Development Report 2016 (Table 2), the most of G20 economies are either at very-high or high human development level (Only Indonesia, South Africa, and India are at medium human development level amongst them). The life expectancy at birth in all G20 economies but South Africa, India, Indonesia, and Russia is higher than the world average of 71.6 years. Among G20 economies, only India's expected years of schooling is lower than the world average of 12.3 years. On the other hand, the mean years of schooling is lower than the world average (8.3 years) in Indonesia, Turkey, Brazil, China, and India. The GNI per capita is below the world average of US $14,447 (in 2011 PPP) in Brazil, China, South Africa, Indonesia, and India amongst G20 economies.

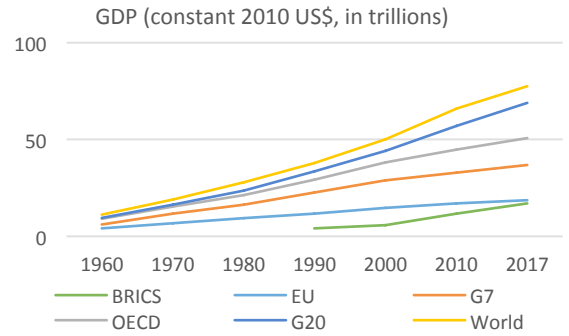
Table 2: G20 economies in UNDP's Human Development Index 2016

HDI rank 2015 (out of 188 economies)	Country	Population (thousands)	Human Development Index (HDI)	Life expectancy at birth	Expected years of schooling	Mean years of schooling	GNI per capita (2011 PPP $)
2	Australia	24,598	0.939	82.5	20.4	13.2	42,822
4	Germany	82,695	0.926	81.1	17.1	13.2	45,000
10	Canada	36,708	0.920	82.2	16.3	13.1	53,245
10	US	325,719	0.920	79.2	16.5	13.2	42,582
16	UK	66,022	0.909	80.8	16.3	13.3	37,931
17	Japan	126,785	0.903	83.7	15.3	12.5	37,268
18	Korea	51,466	0.901	82.1	16.6	12.2	34,541
21	France	67,118	0.897	82.4	16.3	11.6	38,085
26	Italy	60,551	0.887	83.3	16.3	10.9	33,573
38	Saudi Arabia	32,938	0.847	74.4	16.1	9.6	51,320
45	Argentina	44,271	0.827	76.5	17.3	9.9	20,945
49	Russia	144,495	0.804	70.3	15.0	12.0	23,286
71	Turkey	80,745	0.767	75.5	14.6	7.9	18,705
77	Mexico	129,163	0.762	77.0	13.3	8.6	16,383
79	Brazil	209,288	0.754	74.7	15.2	7.8	14,145
90	China	1,386,395	0.738	76.0	13.5	7.6	13,345
113	Indonesia	263,991	0.689	69.1	12.9	7.9	10,053
119	South Africa	56,717	0.666	57.7	13.0	10.3	12,087
131	India	1,339,180	0.624	68.3	11.7	6.3	5,663
	World	***7,530,360***		***71.6***	***12.3***	***8.3***	***14,447***

Source: UNDP Human Development Index 2016, World Development Indicators

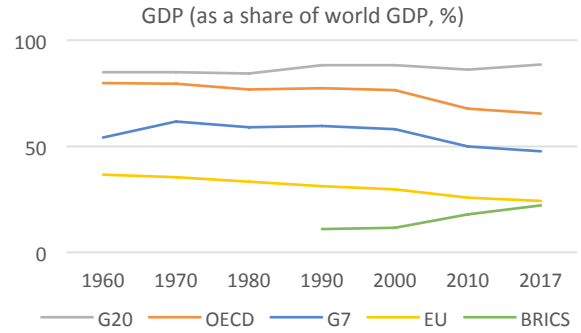
G20 economies produce 88.5% of the global GDP in 2017 (Figures 7-9). None of other economic clubs could reach the level of G20 in this regard. The total G20 GDP in 2017 is US $68.7 trillion in constant 2010 terms. EU and the United States constitute more than half of that figure although their shares have declined since 1990s. China exhibited the most remarkable performance among G20 members and increased its share in total G20 GDP from 2.48% to 14.79% between 1990 and 2017.

Figure 7: Change in GDP of major economic clubs (1960-2017)



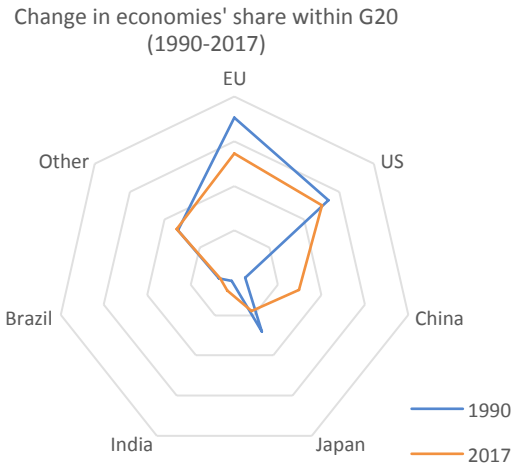
Source: World Development Indicators

Figure 8: Shares of major economic clubs in the world GDP (1960-2017)



Source: World Development Indicators

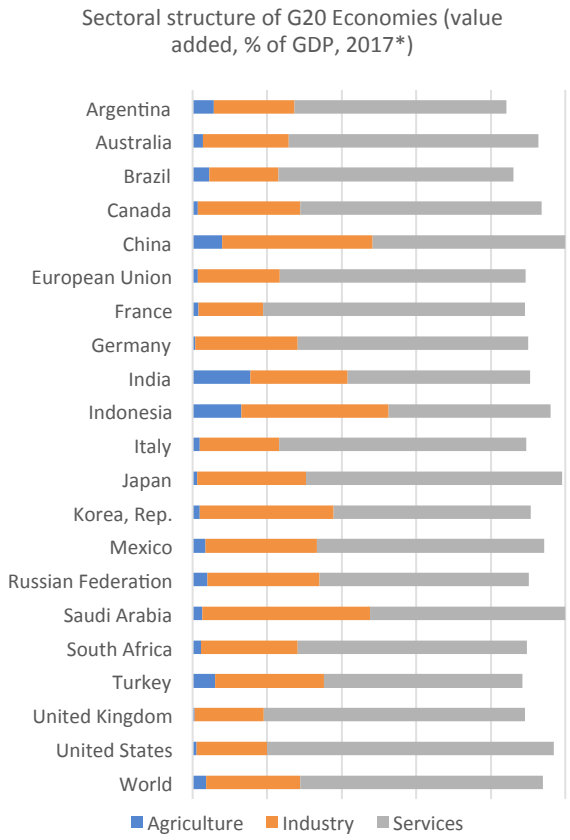
Figure 9: Change in the shares of economies in G20's total GDP (1990-2017)



Source: World Development Indicators

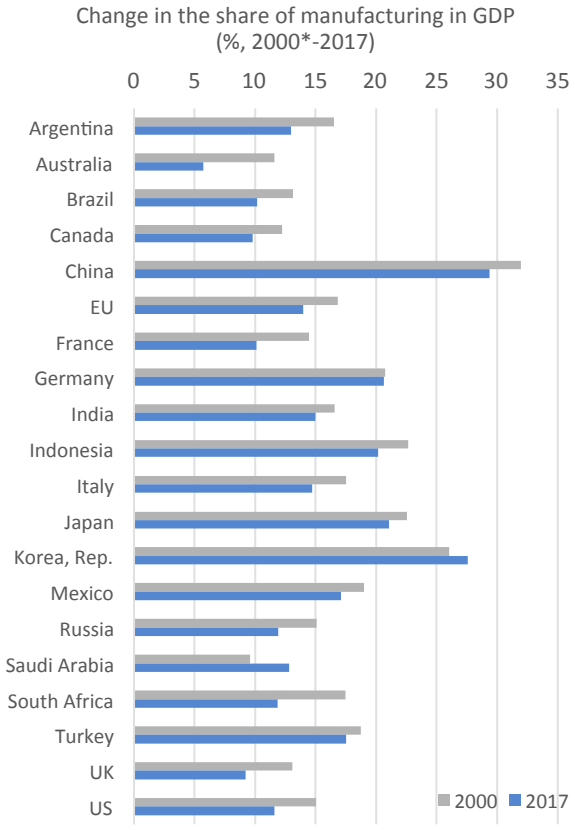
The economy is dominated by services in G20 economies (Figure 10). While the share of services in the economy reaches 77% in the US and is higher than 60% at the most developed members of G20, it is lower than 50% only in India and Indonesia amongst them. Industry (including construction) follow services in most of those economies. Industry constitutes 18 to 40% of the GDP across G20 countries. As evident from Figure 10, the share of industry in GDP is higher than 30% of the GDP only in China (40.4%), Indonesia (39.3%), Korea (35.8%), and Saudi Arabia (44.9%). The share of agricultural sectors in the economy is lower than 5% in 2017 in all G20 economies except India, China, Indonesia, Turkey, and Argentina. The share of manufacturing in GDP has somewhat declined in almost all G20 economies but has increased in Korea and Saudi Arabia since 2000 (Figure 11).

Figure 10: Sectoral structures of G20 economies (2017)



*Source: World Development Indicators, * Canada – 2014, Japan and US – 2016*

Figure 11: Change in the manufacturing's share in G20 economies (2000-2017)

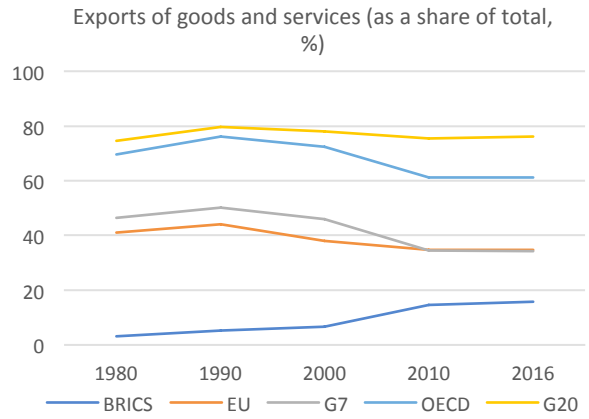


*Source: World Development Indicators, * Canada – 2007, China – 2004, Russian Federation – 2002.*

III. 2 Trade Indicators

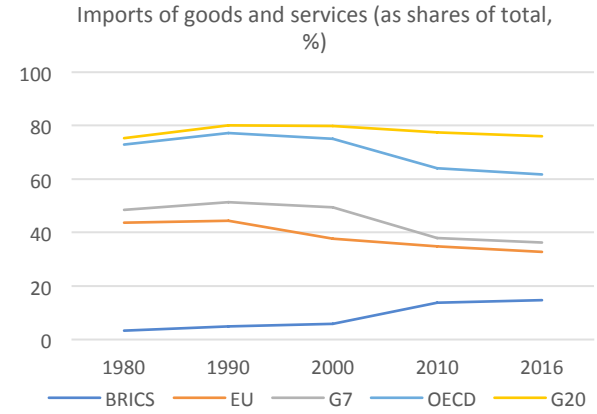
G20 economies lead the international trade in every aspect (Figures 12 and 13). In 2016, 76.2% of total exports of and 76.08% of total imports of goods and services was realized by G20 economies. While the shares of G7, OECD, and EU economies in total exports and imports have declined, G20's shares have remained stable, mostly due to the increased participation of China into the international trade (between 2000 and 2016, China's share in total exports of goods and services increased from 3.19% to 10.53%). Within G20, EU countries go ahead of other economies in terms of both exports and imports although their shares in G20's total exports and imports have been declining. The United States, China, and Japan follow EU regarding both exports and imports of goods and services.

Figure 12: The shares of major economic clubs in the global exports of goods and services (1980-2016)



Source: World Development Indicators

Figure 13: The shares of major economic clubs in the global imports of goods and services (1980-2016)



Source: World Development Indicators

The value of intra-group exports of products (US$ 5.65 trillion, current prices) constituted 58.4% of total exports of products of G20 economies (US$ 9.67 trillion, current prices) while the value of intra-group imports of products (US$ 6.1 trillion, current prices) corresponded to 62.8% of their total imports of products (US$ 9.7 trillion, current prices) in 2016. 58.8% of total manufactured goods (about US$ 4.25 trillion, current prices) was exported to other G20 economies in the same year. The share of intra-group exports in total labor-intensive and resource-intensive manufactures[8] was 55.7%, in total low-skill and technology-intensive manufactures[9] was 49.6%, in total medium-skill and technology-intensive manufactures[10] was 64.5%, and in total high-skill and technology-intensive

[8] Leather, wood manufacture, paper and paperboard, textile yarn, fabrics, woven, floor coverings, lime, cement, mineral manufactures, glass, pottery, furniture & parts, clothing, clothing accessories, footwear etc. (UNCTAD)

[9] Pig iron & spiegeleisen, sponge iron; ingots, primary forms, of iron or steel; rails & railway track construction mat., iron, steel; wire of iron or steel; tubes, pipes & hollow profiles, fittings, iron, steel; wire products (excluding electrical) and fencing grills; nails, screws, nuts, bolts, rivets & the like, of metal; tools for use in the hand or in machine; cutlery; household equipment of base metal; motorcycles & cycles; trailers & semi-trailers; railway vehicles & associated equipment; ships, boats & floating structures; office & stationery supplies etc. (UNCTAD)

[10] Electronics (excluding parts and components), parts and components for electrical and electronic goods; rubber tyres, tyre treads or flaps & inner tubes; internal combustion piston engines, parts; engines & motors, non-electric; rotating

manufactures[11] was 56.5% in 2016. The shares of intra-group imports according to abovementioned groups of manufactures were 64.2%, 68.3%, 75.4%, and 61.01%, respectively.

When we examine the exports of products in terms of the partners income-level of, it appears that G20 economies tend to export their products to high-income economies (Table 3). The share of exports of products to low-income economies varies within the group of G20, but only 0.69% of their exports directed to low-income economies in 2016. Within G20, China, EU, and India were at the top regarding the value of exports of product to low-income economies.

Table 3: G20's exports of products by the income level (*) of partner economies in 2016

	Low-income		Lower-middle income		Upper-middle-income		High-income		Total exports of products
	Value (**)	% (***)	Value (**)	% (***)	Value (**)	% (***)	Value (**)	% (***)	(**)
Argentina	207.6	0.36	10,861	18.81	23,601	40.88	22,329	38.68	57,733
Australia	460.2	0.24	20,103	10.60	69,769	36.79	93,502	49.31	189,629
Brazil	765.1	0.41	16,505	8.91	76,270	41.18	89,959	48.57	185,235
Canada	462	0.12	8,512	2.19	30,171	7.75	349,880	89.93	389,071
China	26,952	1.28	303,186	14.45	292,325	13.94	1,473,974	70.27	2,097,637
EU	19,066	0.35	202,648	3.77	699,589	13.01	4,395,655	81.77	5,375,326
France	4,546	0.93	28,045	5.74	64,846	13.26	390,509	79.88	488,885
Germany	2,008	0.15	41,826	3.12	223,663	16.68	1,065,683	79.48	1,340,752
India	13,328	5.12	34,195	13.14	44,516	17.10	168,284	64.64	260,326
Indonesia	959	0.66	26,559	18.38	35,984	24.90	80,979	56.05	144,489
Italy	1,381	0.30	22,419	4.86	74,982	16.25	358,281	77.63	461,529
Japan	2,104	0.33	54,318	8.42	191,203	29.65	397,266	61.60	644,932
Korea	4,964	1.00	70,753	14.28	186,843	37.71	232,818	46.99	495,417
Mexico	137.8	0.04	7,647	2.05	20,955	5.60	345,057	92.29	373,892
Russia	809.6	0.28	29,211	10.23	86,429	30.27	168,952	59.18	285,491
S. Arabia	2,355	1.13	39,154	18.86	45,826	22.08	120,234	57.92	207,572
S. Africa	6,687	9.02	11,453	15.46	17,148	23.14	34,253	46.22	74,110
Turkey	1,577	1.11	15,209	10.67	33,430	23.45	89,556	62.83	142,529
UK	1,139	0.28	15,708	3.82	46,269	11.25	342,971	83.35	411,463
US	4,798	0.33	80,733	5.57	491,201	33.87	873,646	60.23	1,450,457
G20 Total	***85,637***	***0.69***	***931,055***	***7.52***	***2,345,265***	***18.95***	***8,936,351***	***72.22***	***12,373,853***
World	***122,037***	***0.76***	***1,387,606***	***8.66***	***3,456,007***	***21.56***	***10,959,812***	***68.39***	***16,026,140***

Source: UNCTAD, (*) According to the World Bank classification, (**) In millions of current US $, (***) The share in the exports of products of the economy

Although their share has been declining since 2000s, Northern America and Europe are still the favorite destination for the goods exported from G20 economies (Figure 14). In 2016, 57.9% of total exports of goods was directed to these regions. Sub-Saharan Africa gets the smallest portion from G20's good exports; its share constituted only 1.9% of total exports of goods in 2016.

electric plant & parts; agricultural machinery & parts; tractors; civil engineering & contractors' plant & equipment; textile & leather machinery & parts; metalworking machinery (excluding machine-tools) & parts; electric power machinery, and parts; equipment for distributing electricity etc. (UNCTAD)

[11] Office machines , automatic data processing machines, television receivers, radio-broadcast receivers, sound recorders or reproducers; telecommunication equipment, cathode valves & tubes; organic and inorganic chemicals; radio-actives and associated materials; medicinal and pharmaceutical products; aircraft & associated equipment; optical instruments & apparatus; arms & ammunition etc. (UNCTAD)

Figure 14: G20 economies' exports of goods by partner region (1995-2016)

Source: UNCTAD

Table 4: Exports of goods in high-technology industries

	2000		2010		2016	
	Value (*)	% (**)	Value (*)	% (**)	Value (*)	% (**)
China	55.73	4.00	513.73	19.83	652.79	21.97
EU	193.82	13.90	387.97	14.98	476.35	16.03
Germany	100.38	7.20	222.67	8.59	260.89	8.78
US	236.66	16.98	193.46	7.47	208.25	7.01
Korea	63.45	4.55	140.38	5.42	145.77	4.91
France	71.20	5.11	130.81	5.05	133.48	4.49
Japan	151.81	10.89	138.46	5.34	118.84	4.00
UK	83.01	5.95	88.70	3.42	108.20	3.64
Mexico	41.58	2.98	72.92	2.81	82.60	2.78
Italy	27.37	1.96	45.31	1.75	48.76	1.64
Canada	31.61	2.27	28.09	1.08	30.71	1.03
India	1.99	0.14	15.24	0.59	24.84	0.84
Brazil	6.83	0.49	9.40	0.36	10.52	0.35
Australia	4.48	0.32	8.94	0.34	9.79	0.33
Indonesia	8.25	0.59	8.85	0.34	7.35	0.25
Russia	1.95	0.14	3.68	0.14	5.83	0.20
Turkey	1.98	0.14	3.58	0.14	4.65	0.16
S. Africa	1.00	0.07	2.31	0.09	2.73	0.09
S. Arabia	0.02	0.00	0.23	0.01	1.75	0.06
Argentina	0.78	0.06	1.69	0.07	1.58	0.05
G20	***801.94***	***57.52***	***1,528.91***	***59.01***	***1,784.35***	***60.05***
World Total	***1,394.16***		***2,590.73***		***2,971.57***	

Source: World Integrated Trade Solution (WITS) (https://wits.worldbank.org/about_wits.html)
(*) Current US$ billions (**) Share in world total.

In high-technology industries[12], the share of G20 economies in total exports of goods increased to 60.05% in 2016 from 57.52% in 2000 (Table 4). We observe a remarkable change regarding the high-technology industries' exports of G20 economies. While the shares of US, Japan, UK, and some other western developed countries in exports in high-technology industries declined, China's share considerably increased between 2000 and 2016.

[12] Aircraft and spacecraft; Pharmaceuticals; Office, accounting and computing machinery; Radio, TV and communications equipment; Medical, precision and optical instruments. (According to ISIC REV. 3 Technology Intensity Definition)

About two third of the exports of high-technology industries of G20 economies went to high-income economies in 2016 (Table 5). The portion that went to the least developed countries (LDCs) was only 0.86% of the total. Within G20, South Africa, due to its geographical proximity to LDCs in Africa, came at first regarding the share of exports in high-tech industries to LDCs, while China and France were the major exporters to LDCs in that regard.

Table 5: High-tech goods exports of G20 economies by the income level of partners (2016)

	All countries	High-income economies		Least Developed Countries		Low- and middle-income economies	
	Value (*)	Value (*)	% (**)	Value (*)	% (**)	Value (*)	% (**)
Argentina	1,585	574	36.20	2	0.10	981	61.90
Australia	9,790	7,218	73.73	81	0.82	2,364	24.14
Brazil	10,524	7,933	75.39	62	0.59	2,459	23.36
Canada	30,711	26,661	86.81	109	0.36	3,082	10.04
China	652,788	497,996	76.29	5,707	0.87	118,982	18.23
EU	260,887	185,900	59.32	467	1.11	50,651	33.96
France	476,349	282,555	66.52	5,289	1.61	161,777	27.58
Germany	133,480	88,796	71.26	2,154	0.18	36,812	19.41
India	108,197	87,016	57.73	451	8.67	14,458	38.48
Indonesia	7,345	5,490	74.74	93	1.27	1,576	21.45
Italy	24,838	14,339	78.81	2,152	0.28	9,556	15.45
Japan	48,756	38,426	51.97	136	0.17	7,531	36.68
Korea	118,841	61,766	36.99	201	0.17	43,587	57.77
Mexico	145,774	53,924	93.35	251	0.03	84,207	6.14
Russia	82,603	77,114	18.71	27	3.54	5,068	79.73
S. Africa	5,830	1,091	41.98	207	16.83	4,648	54.72
S. Arabia	1,748	1,379	78.87	10	0.58	285	16.30
Turkey	4,651	3,150	67.72	62	1.34	1,081	23.25
UK	208,246	128,365	80.42	602	0.42	67,042	13.36
US	2,729	1,146	61.64	459	0.29	1,493	32.19
G20	***1,784,351***	***1,170,699***	***65.61***	***15,314***	***0.86***	***508,189***	***28.48***

Source: World Integrated Trade Solution (WITS) (https://wits.worldbank.org/about_wits.html)
(*) Current US$ millions (**) Share in the economy's total exports in high-tech industries.

The share of LDCs in the capital goods exports of G20 economies is somewhat larger than their share in G20's high-tech industries' exports, yet it was just above 1% of the total in 2016 (Table 6). While the share of low- and middle-income economies in the capital goods exports of G20 economies was 36.07% in the same year. We rightly suppose that the import of capital goods is one of the ways of technology transfer from abroad and countries get disembodied technology in this way. In this regard, China, EU, and India appear as the most important disembodied technology sources for LDCs while EU, China, Korea, and US are the main knowledge sources for low- and middle-income economies.

Table 6: Exports of capital goods of G20 economies by the income level of partners (2016)

	All countries	High-income economies		Low- and middle-income economies		Least Developed Countries (LDCs)	
	Value (*)	Value (*)	% (**)	Value (*)	% (**)	Value (*)	% (**)
Argentina	1,016	213	20.96	794	78.15	4	0.36
Australia	9,084	5,765	63.47	3,032	33.37	157	1.73
Brazil	14,987	8,309	55.44	6,555	43.74	103	0.69
Canada	32,383	28,084	86.73	3,868	11.94	97	0.30
China	835,639	595,346	71.24	195,336	23.38	12,118	1.45
EU	484,054	225,343	46.55	234,453	48.44	7,520	1.55
France	83,686	56,021	66.94	21,239	25.38	1,242	1.48
Germany	354,587	211,702	59.70	95,031	26.80	1,428	0.40
India	23,273	12,261	52.68	9,815	42.17	2,320	9.97
Indonesia	9,890	6,805	68.81	2,741	27.71	91	0.92
Italy	111,408	65,736	59.01	34,637	31.09	1,147	1.03
Japan	215,494	103,685	48.11	94,002	43.62	821	0.38
Korea	205,236	73,699	35.91	121,055	58.98	561	0.27
Mexico	105,586	99,952	94.66	5,103	4.83	35	0.03
Russia	9,521	1,534	16.11	7,352	77.22	241	2.53
S. Arabia	2,451	1,918	78.26	369	15.08	34	1.37
S. Africa	6,687	2,447	36.59	4,006	59.91	1,671	24.99
Turkey	12,241	4,961	40.53	5,505	44.98	349	2.85
UK	74,013	54,340	73.42	14,111	19.07	689	0.93
US	256,614	133,805	52.14	108,370	42.23	1,517	0.59
G20 - Total	***2,224,156***	***1,304,126***	***58.63***	***802,357***	***36.07***	***27,638***	***1.24***

Source: World Integrated Trade Solution (WITS) (https://wits.worldbank.org/about_wits.html)
(*) Current US$ millions (**) Share in the economy's total exports of capital goods.

According to UNCTAD's data, the value of services exported by G20 economies was US$ 4.15 trillion, which corresponds to 77.6% of total exports of services around the world in 2017. We see the control of G20 economies in knowledge-intensive services, too. G20 economies exported 90.5% of R&D services, 84.8% of computer services (software and other related services), and 93.8% of information services in 2017. On the other hand, G20 economies also the main importer of services. They were the destination of 76.7% of total imports of services around the world in 2017. The charges for the use of intellectual property[13] that was paid to G20 economies increased from US$ 154.5 billion in 2005 to US$ 340.7 billion in 2017, which was 89.5% of total exports of intellectual property around world in that year.

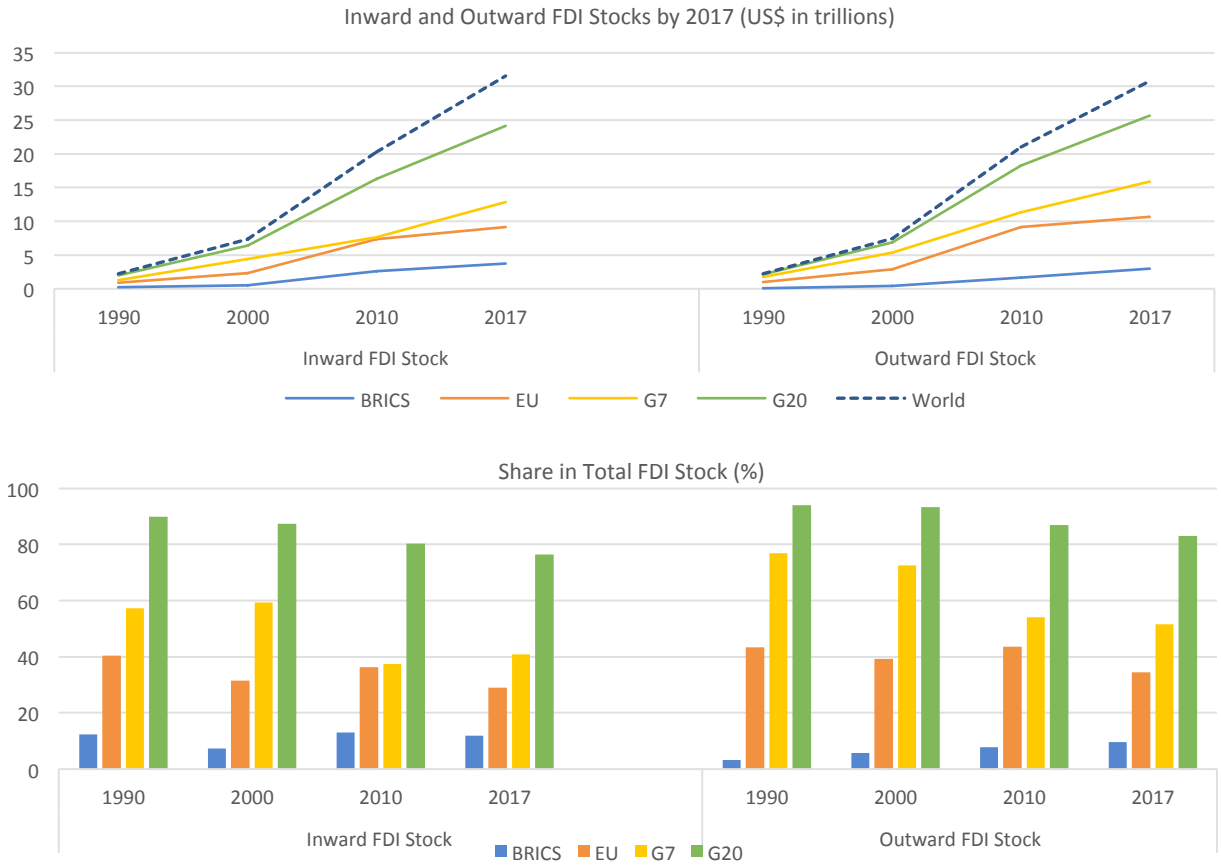
III.3 FDI Indicators

G20 economies play a central role in foreign direct investments (FDI). According to UNCTAD's World Investment Report (WIR) 2018, the share of G20 economies in inward FDI stock has been declining (from 89.84% in 1990 to 76.50% in 2017). Yet, these economies are still the main destinations for FDI (Figure 15). G20 economies are also the most important source of the outward FDI, though their

[13] Includes: (a) charges for the use of proprietary rights (such as patents, trademarks, copyrights, industrial processes and designs including trade secrets, franchises) and (b) charges for licenses to reproduce or distribute (or both) intellectual property embodied in produced originals or prototypes (such as copyrights on books and manuscripts, computer software, cinematographic works, and sound recordings) and related rights (such as for live performances and television, cable, or satellite broadcast). (UNCTAD)

share in total outward FDI stock declined from 93.97% in 1990 to 83.14% in 2017. Within G20, EU, the United States, and China are the most favorite destinations for foreign direct investments.

Figure 15: Inward and outward FDI Stocks



Source: UNCTAD

UNCTAD's ranking of non-financial MNEs by the value of their foreign assets in 2017 shows that 91 of top 100 non-financial MNEs are from G20 economies (including EU countries) (Table 7). The United States was home to 20 of those MNEs, while 14 of them were based from the United Kingdom, 12 from France, 11 from Germany, and 11 from Japan. 52 of these 91 MNEs operate in industrial sectors in which knowledge is an important asset such as aircraft, communications equipment, motor vehicles, and pharmaceuticals. The value of foreign assets of those 91 MNEs was around US$ 8.3 trillion and they employed about 8.37 million people abroad by 2017. If we focus on developing and transition economies, UNCTAD's data[14] shows that 71 of top 100 non-financial MNEs were from G20 economies by the same year. 37 of these 71 MNEs were from China (including Hong Kong) while Mexico (7), Korea (6), South Africa (6), India (6), Brazil (5), Russia (2), Argentina (1), and Saudi Arabia (1) followed China in that regard.

[14] http://unctad.org/Sections/dite_dir/docs/WIR2018/WIR18_tab20.xlsx

Table 7: Top-100 non-financial MNEs by home economies

Home economy*	Number of corporations in top 100 non-financial MNEs	Assets (US$, in millions - 2017)		Sales (US$, in millions - 2017)		Employment (number – 2017)	
		Foreign	Total	Foreign	Total	Foreign	Total
Australia	1	55,191	116,985	35,567	37,565	10,240	26,146
Belgium	1	165,176	205,173	38,429	47,052	156,544	200,000
Canada	2	107,374	199,477	26,869	44,547	8,419	19,479
China **	5	362,383	631,508	107,105	249,092	603,598	970,496
Finland	1	42,816	49,201	24,182	26,096	95,372	101,731
France	12	899,070	1,550,236	499,835	694,513	979,197	1,565,754
Germany	11	1,073,679	1,855,384	799,779	1,045,373	1,560,290	2,694,709
Ireland	4	296,743	337,824	67,994	90,263	192,223	252,844
Israel	1	50,641	70,739	17,445	21,629	45,546	51,791
Italy	2	238,756	324,501	82,215	157,365	44,412	96,436
Japan	11	1,215,285	1,995,636	657,524	1,085,937	907,549	1,737,354
Korea	1	83,371	282,814	183,963	211,859	215,541	308,745
Luxembourg	1	68,678	71,104	57,159	57,252	118,465	197,108
Netherlands	1	83,710	86,876	24,273	26,494	45,454	47,173
Norway	1	59,732	111,100	13,414	60,971	2,613	20,245
Singapore	1	52,764	54,418	17,313	17,636	13,100	14,000
Spain	3	262,502	342,542	113,864	140,856	127,259	181,199
Sweden	1	43,756	50,255	38,123	39,179	67,139	87,104
Switzerland	5	407,462	546,280	337,837	416,365	600,662	766,268
Taiwan	1	95,809	114,824	151,752	154,650	728,431	873,000
United Kingdom	14	1,501,807	1,747,604	769,467	1,000,805	925,963	1,212,660
United States	20	1,841,202	3,750,152	1,107,012	2,339,216	2,315,926	5,224,710

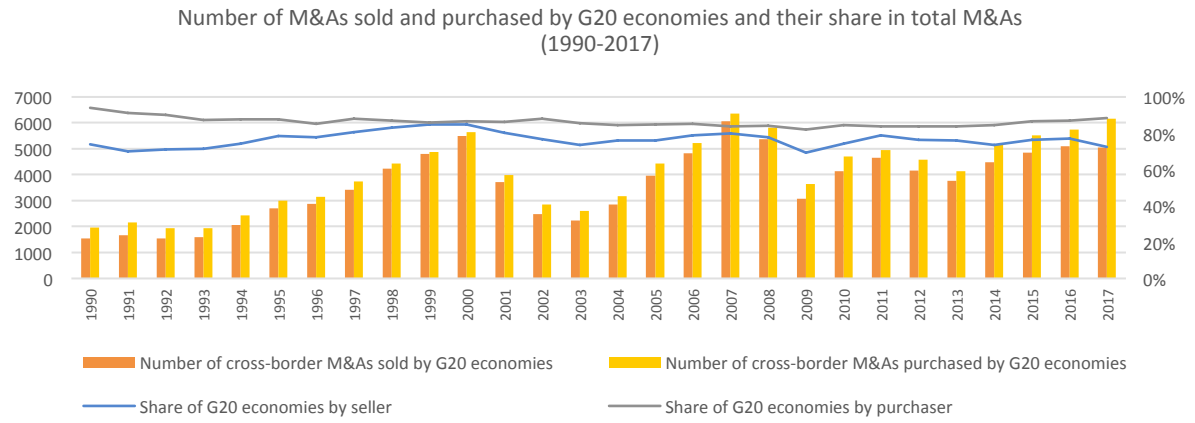
Source: UNCTAD's World Investment Report 2018 [15]

** Shaded are G20 economies (including EU countries), **Includes Hong Kong*

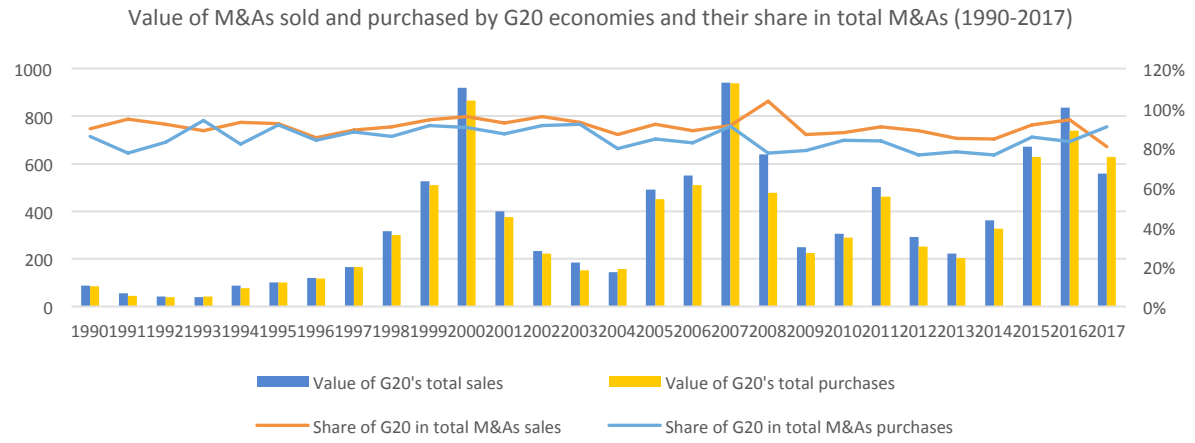
Data related to the cross-border mergers and acquisitions (M&As or brownfield investments) and greenfield investments confirm the control of G20 economies on FDI. According to UNCTAD's World Investment Report 2018, G20 economies appear both as the top sellers and purchasers in terms of the net cross-border M&As. As shown by Figure 16, there were sharp fluctuations in the shares of G20 economies in the total cross-border M&As during the global crises (2001 and 2008) in parallel to the global trend. Yet, the shares of G20 economies in the total cross-border M&As has remained stable over time. We could observe similar trends and fluctuations in the values of M&As materialized between 1990 and 2017. That figures provide reasonable grounds to suppose that a large part of the global M&As occurred among G20 economies. Yet, the disparities among G20 economies regarding M&As should be underlined. UNCTAD's data shows that 71.32% of total M&A sales and 58.28% of total M&A purchases were made by EU countries (particularly by the United Kingdom) and the United States between 1990 and 2017. On the other hand, the shares of Argentina, India, Indonesia, Korea, Mexico, Russia, Saudi Arabia, South Africa, and Turkey in the total M&As as seller and purchaser were less than 1% in the same period.

[15] http://unctad.org/Sections/dite_dir/docs/WIR2018/WIR18_tab19.xlsx

Figure 16: Cross-border M&As of G20 economies



Source: UNCTAD's World Investment Report 2018[16]

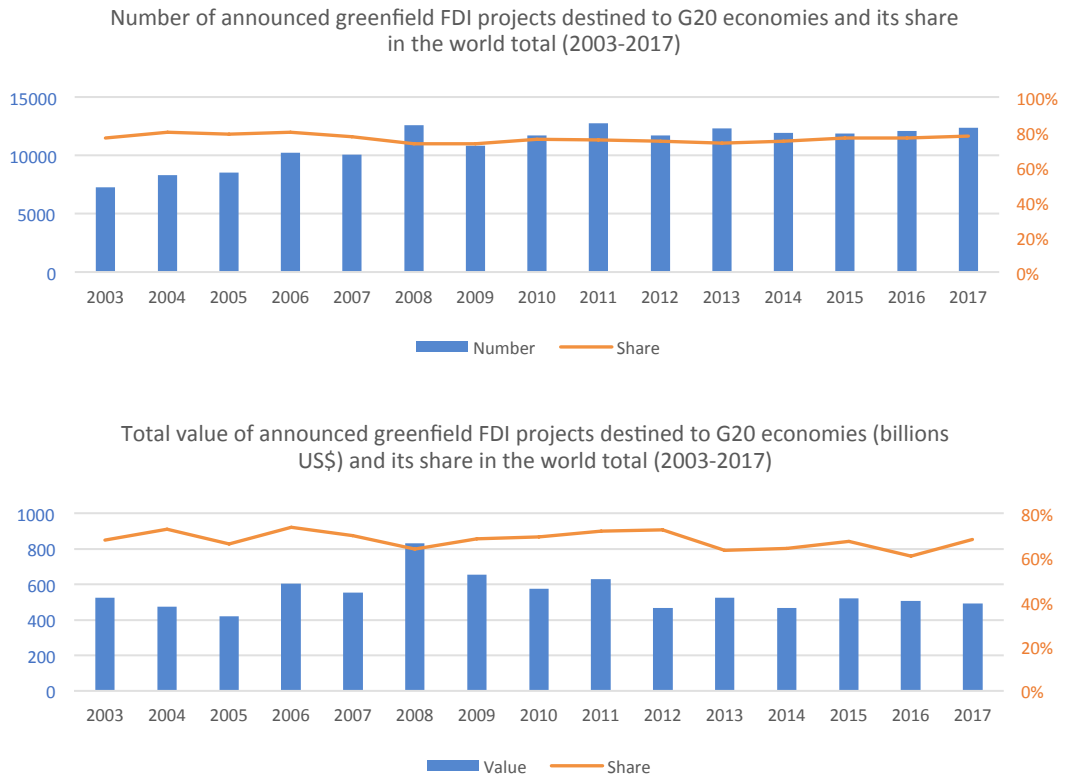


Source: UNCTAD's World Investment Report 2018[17]
Since the financial centers in the Caribbean are excluded from the total M&As around the world, G20's share may exceed world total.

G20 economies are also the most preferred destinations for the greenfield FDI projects (Figure 17). According to World Investment Report 2018 of UNCTAD, G20 economies were announced as the destination for 76.07% of the greenfield FDI projects around the world between 2003 and 2017. The value of these projects constituted 67.79% of the total greenfield FDI projects announced around the world in the same period. EU countries attracted 34.21% of the total announced greenfield FDI projects in the same period. China (includes Hong Kong) and the United States followed EU with shares of 10.05% and 9.27%, respectively.

[16] http://unctad.org/Sections/dite_dir/docs/WIR2018/WIR18_tab08.xlsx and http://unctad.org/Sections/dite_dir/docs/WIR2018/WIR18_tab07.xlsx
[17] http://unctad.org/Sections/dite_dir/docs/WIR2018/WIR18_tab06.xlsx and http://unctad.org/Sections/dite_dir/docs/WIR2018/WIR18_tab05.xlsx

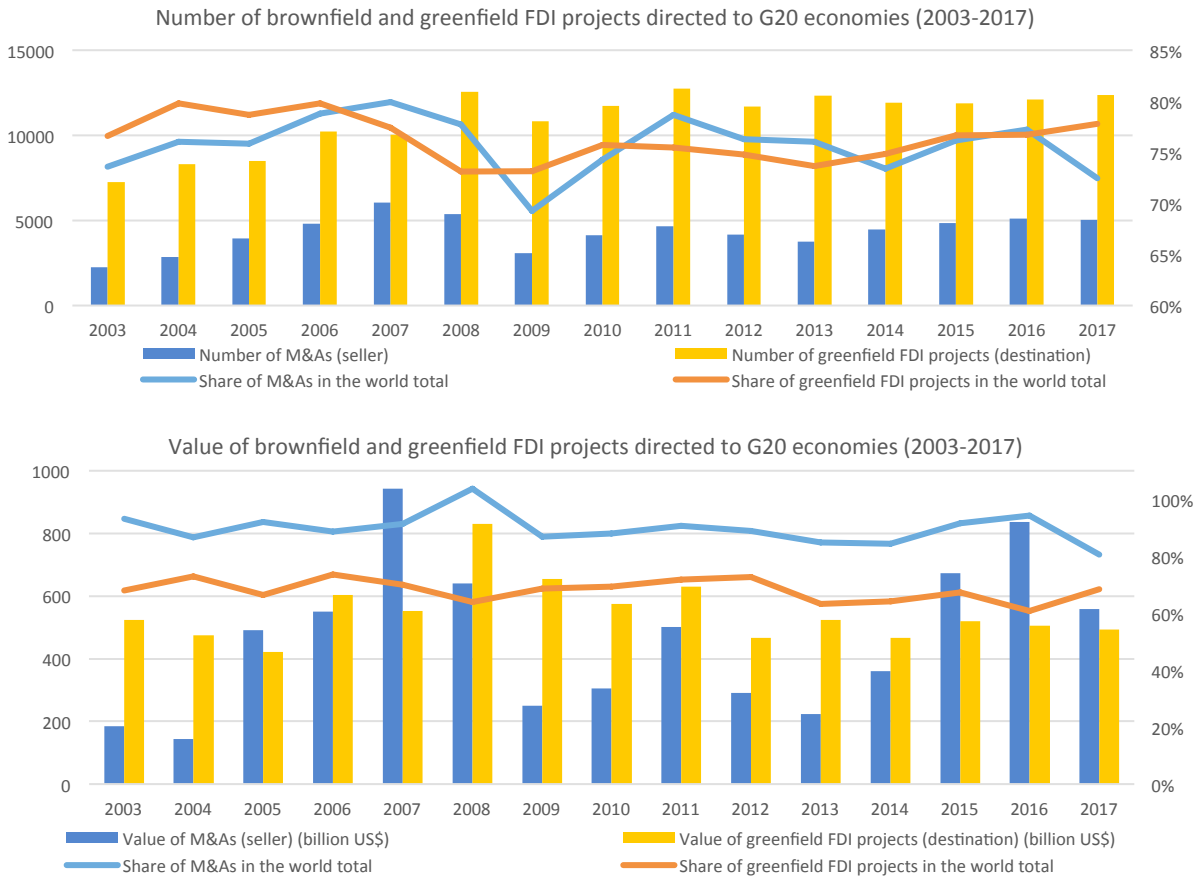
Figure 17: Greenfield FDI towards G20 economies (2003-2017)



Source: UNCTAD's World Investment Report 2018

The number of greenfield FDI projects destined to G20 economies was significantly more than the number of M&As sold by G20 economies between 2003 and 2017 (Figure 18). Though, the total values of greenfield FDI projects destined to G20 economies remained at low levels compare to M&As sold by those economies. Furthermore, the global brownfield FDI projects were more concentrated on some economies than the brownfield FDI projects in terms of both numbers and values. Between 2003 and 2017, the total values of M&As sold by North American (the United States and Canada) and European Union countries constituted 74.53% of the world total whereas the total values of the greenfield FDI projects destined to these economies were just 30.13% of the world total. China (including Hong Kong) and India, for example, appears as important destinations for the greenfield FDI projects according to UNCTAD's data.

Figure 18: Brownfield vs. greenfield FDI inward G20 economies



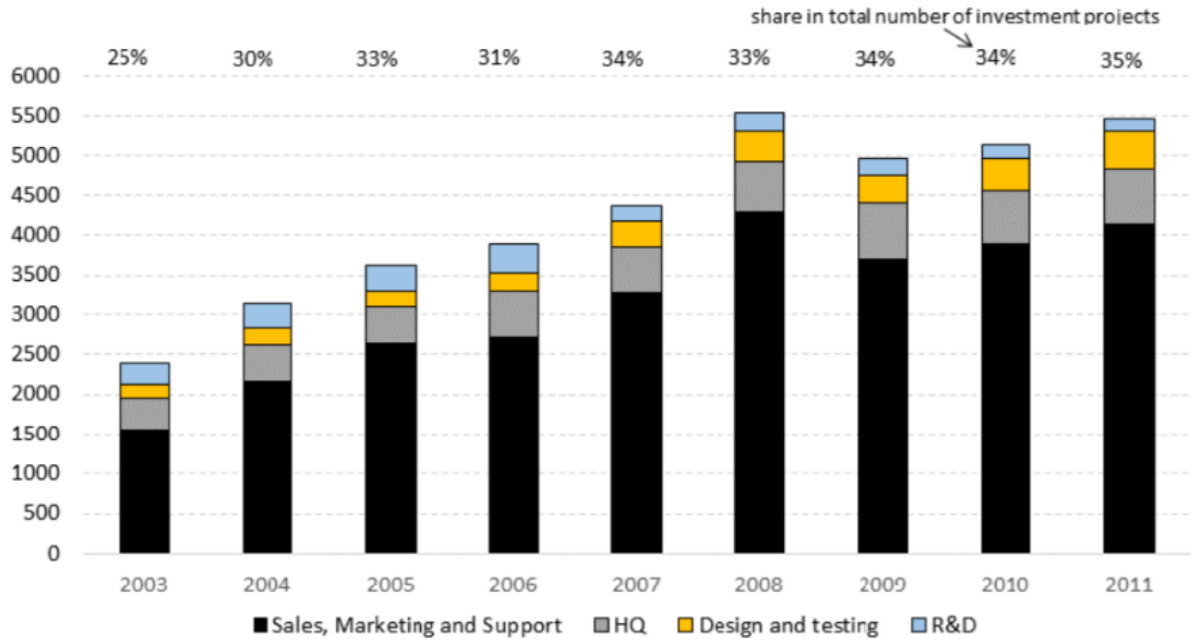
Source: UNCTAD's World Investment Report 2018

The data related to FDI in R&D is limited. However, some studies provide indicative insights about the role of G20 economies regarding internationalization of R&D. It should be underlined that R&D is the least internationalized activity of MNEs mainly due to the tacit nature of knowledge. Belderbos et al. (2016) confirm that fact by analyzing FDI Markets[18] database. Their analysis of data belongs to the period of 2003-2011 shows that about two third of the cross-border investments were production-related. The investments on sales, marketing, and support activities constituted the largest part of the rest. Together with the investments on headquarters, R&D, and design and test activities were just 8-9% of the total cross-border investments in the same period (Figure 19). The share of production in total cross-border investments varied across countries. While their share was about 50-55% in relatively more developed countries such as the United States, Germany, and Japan, that figure was at higher levels in emerging economies (70% in China and Brazil, 84% in Indonesia e.g.). The FDI in R&D was more concentrated on OECD countries, particularly the United States and Europe (Belderbos et al., 2016). Castellani (2017) indicates that only 1,600 cities received at least one FDI in R&D while manufacturing-related FDIs dispersed 6,500 cities around the world between 2003 and

[18] https://www.fdimarkets.com/

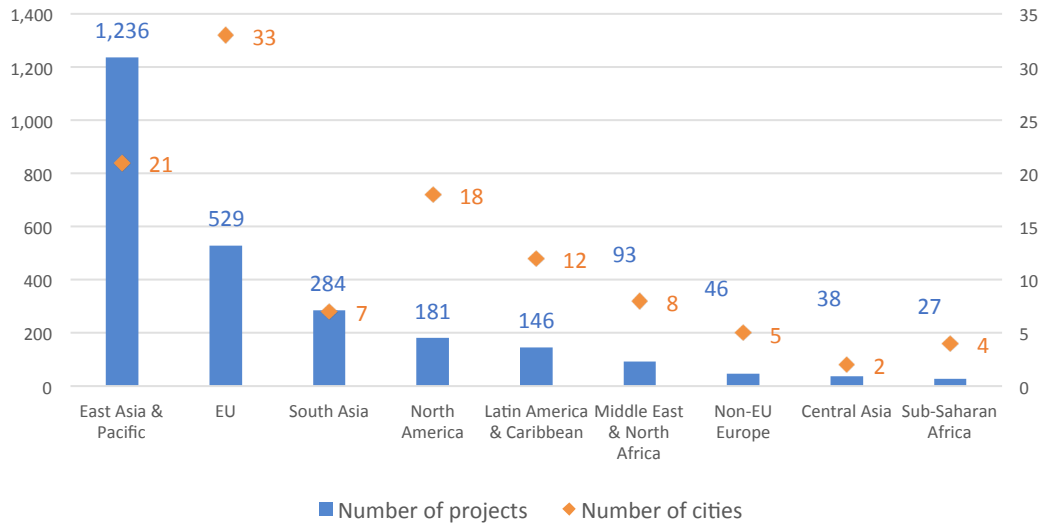
2014. Furthermore, 60% of the R&D FDI projects destined to only 100 cities. Castellani and Lavoratori's (2017) study of 2,580 new greenfield investments in R&D and design, development and testing (DDT) made by 1,316 MNEs between 2003 and 2014 show that these projects were located in 110 cities around the world. According to the study, 21 cities in East Asia and Pacific (EAP) region attracted 1,236 new greenfield investments in R&D and DDT. 33 cities from EU and 7 cities from South Asia followed EAP with 529 and 284 projects, respectively (Figure 20). In the same period, only 4 cities in Sub-Saharan Africa could attract 27 of cross-border R&D and DDT projects. The distribution of projects by region in which the investor MNEs originated show that 91.58% of FDI in R&D and DDT projects were from North America, EU, and East Asia and Pacific regions in the period of 2003-2014 (Castellani & Lavoratori, 2017). Since the majority of G20 economies are in these regions, it could be easily speculated that a large part of FDI in R&D of G20 economies are intra-group transactions (Figures 20 and 21). That fact may limit the transfer of knowledge from G20 economies through developing and less developed areas of the world.

Figure 19: Number of investment projects in up- and downstream support activities, 2003-2011



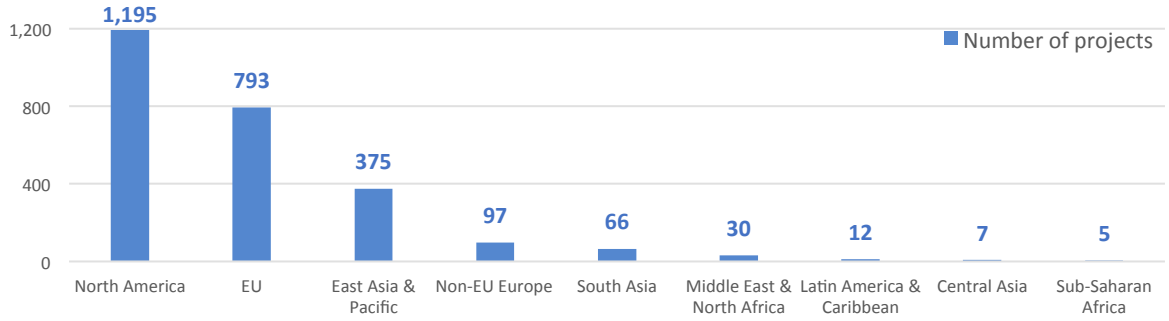
Source: Belderbos et al. (2016)

Figure 20: Geographical distribution of R&D/DDT projects, by destination (2003-2014)



Source: Castellani & Lavoratori (2017)

Figure 21: Geographical distribution of R&D/DDT projects, by origin (2003-2014)

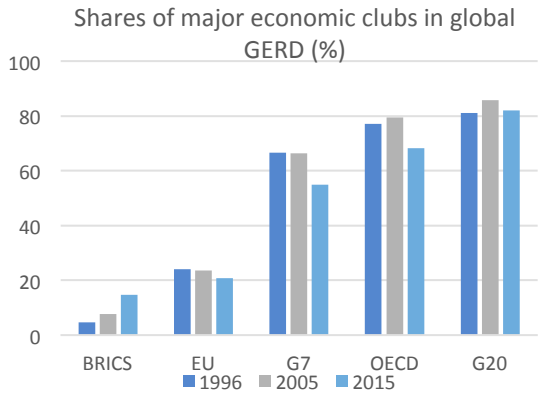


Source: Castellani & Lavoratori (2017)

III. 4 STI Inputs

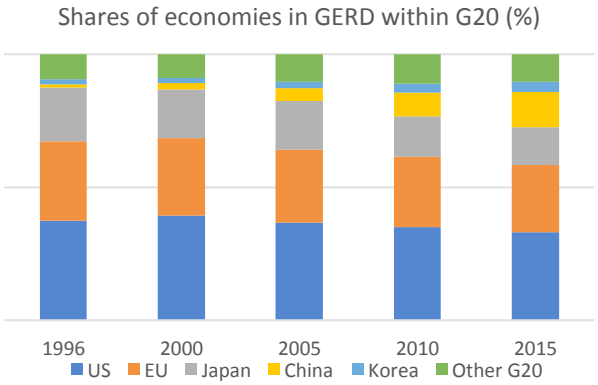
Although their share in the global gross expenditure on R&D (GERD) declined between 2010 and 2015, due to the deceleration of R&D spending in developed countries, G20 economies still dominate the global R&D (Figure 22). In 2015, these economies spent 82.11% of the global GERD. Within G20, the United States, European Union countries (particularly Germany, France, and the United Kingdom), Japan, and China lead R&D activities. The increase in China's share in G20's GERD in the last two decades (from 1.31% in 1996 to 13.22% in 2015) is remarkable (Figure 23).

Figure 22: Change in the shares of major economic clubs in global GERD (%)



Source: OECD Main Science and Technology Indicators 2018-1 and World Development Indicators

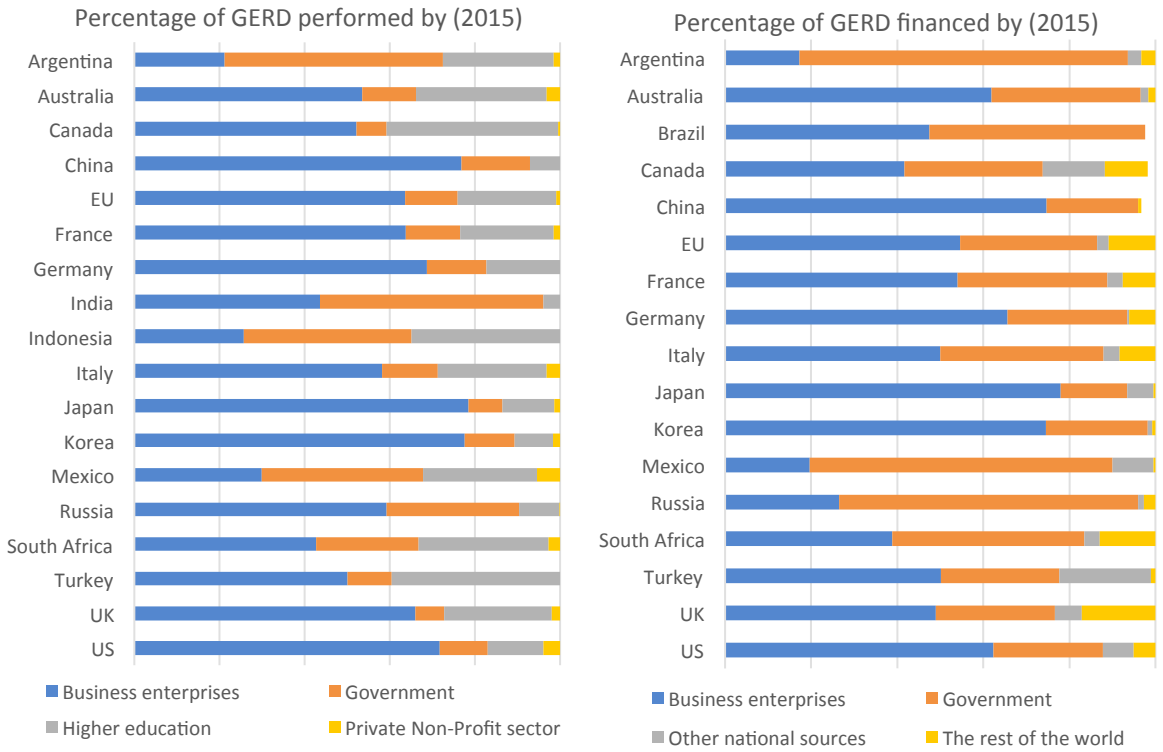
Figure 23: Change in the shares of economies in total GERD of G20



Source: OECD Main Science and Technology Indicators 2018-1 and World Development Indicators

The business enterprises are more influential in performing of R&D activities in the most developed members of G20 (Figure 24). While, the R&D activities of governments are at significantly higher levels in Argentina, India, Indonesia, Mexico, and Russia. In Australia, Canada, Indonesia, South Africa, and Turkey, universities performed more than 30% of R&D activities in 2015. Business enterprises appear as the main funder of R&D activities in most of G20 economies. Yet, government is still an important resource for R&D in many countries. The relatively large share of R&D activities financed by foreign resources in European countries reflects the significant contribution of EU's Research and Innovation Framework Programs.

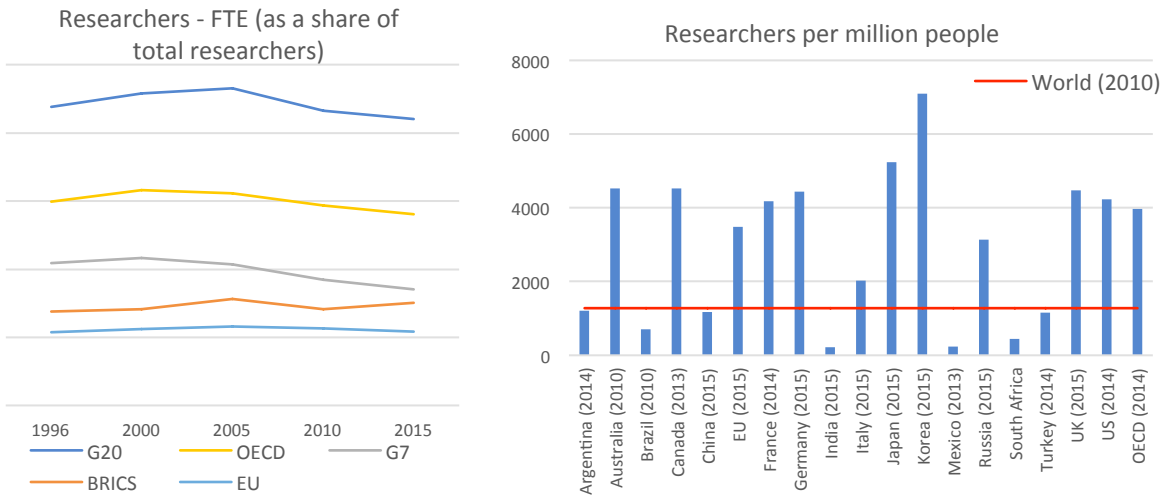
Figure 24: Performers and financiers of GERD in G20 economies



Source: OECD Main Science and Technology Indicators 2018-1 and UNESCO

According to OECD and UNESCO's data, G20 economies host 84.1% of researchers (FTE). The number of researchers (headcount) in R&D per million inhabitants vary across G20 economies (Figure 25). That figure surpassed 3,000 in 10 (including EU) members of G20 between 2010 and 2015 whereas the world average was 1,277 in 2010 according to World Development Indicators. Brazil, South Africa, India, and Mexico remained at lower levels in this regard.[19]

Figure 25: Researchers in G20 economies



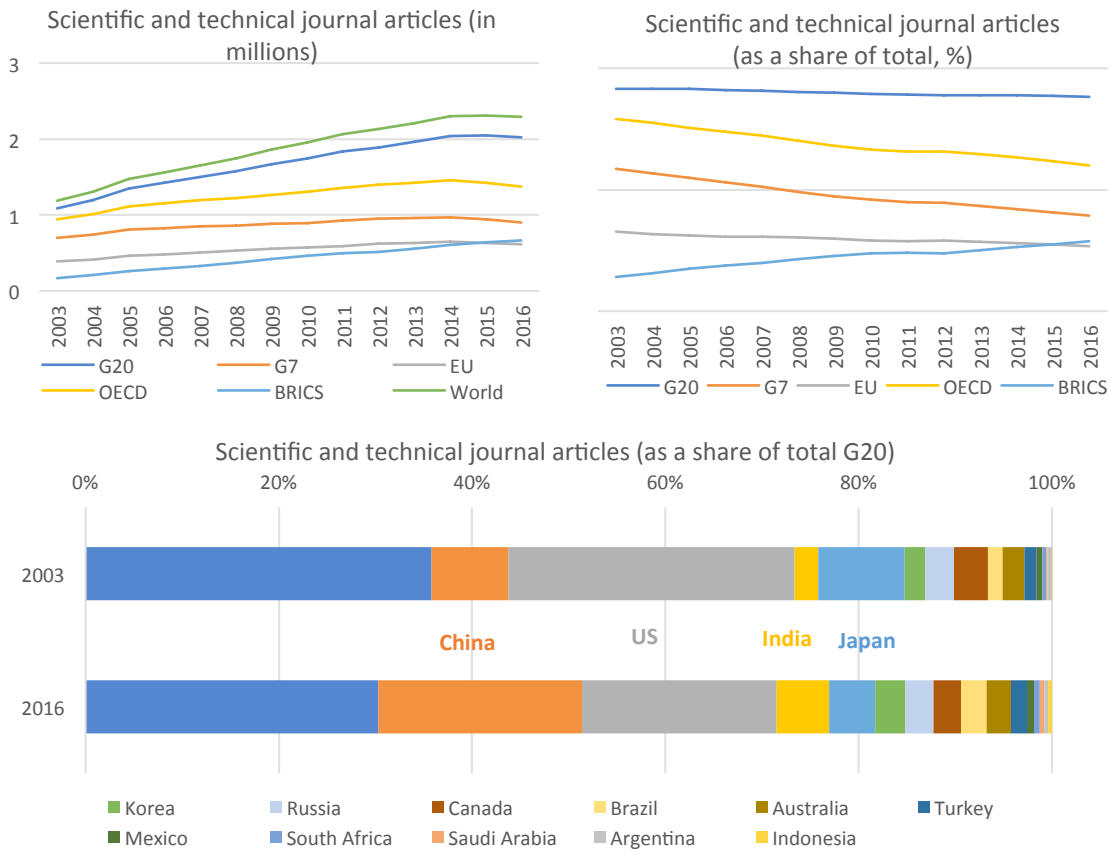
Source: OECD Main Science and Technology Indicators 2018-1 and World Development Indicators

[19] Data is not available for Saudi Arabia and Indonesia.

III. 5 STI Outputs

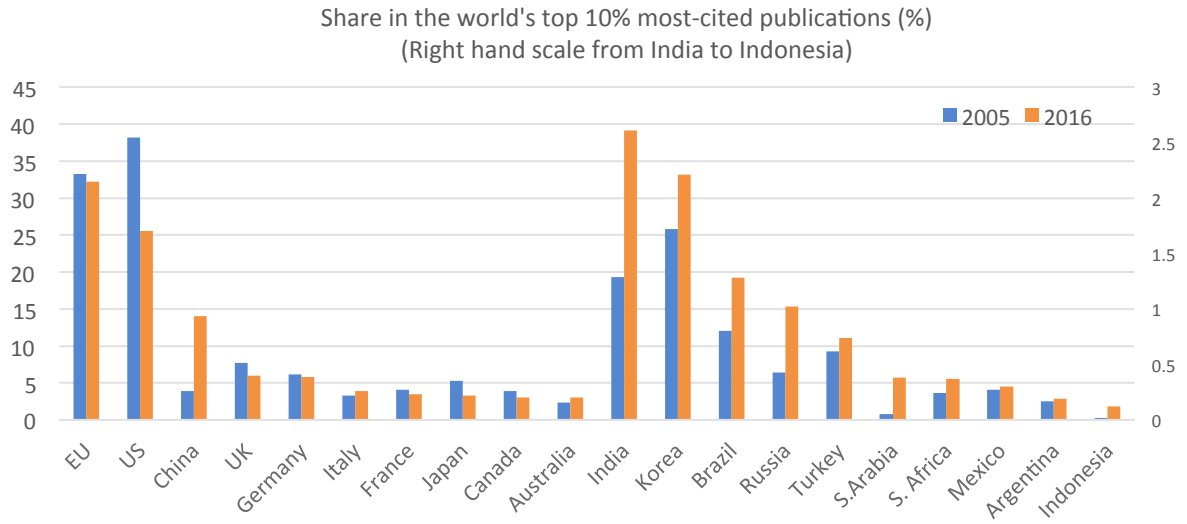
By 2016, G20 economies produce 88.2% of the total scientific and technical articles (Figure 26). While G20's share in the total scientific and technical articles somewhat remained at the same levels between 2003-2016, the shares of other major economic clubs, except BRICS, remarkably declined. Within G20, EU countries lead the way in scientific and technical publications. China, by dramatically increasing the number of its scientific and technical articles from 86,621.4 in 2003 to 426,165.3 in 2016, and United States follow EU in this regard. EU, US, and China are ahead of other G20 economies regarding the quality of the scientific publications. Increases in the shares of China in the most cited publications in the recent years should be underlined (Figure 27).

Figure 26: Scientific publications of major economic clubs



Source: World Development Indicators

Figure 27: Share of G20 economies in the most cited publications



Source: OECD STI Scoreboard 2017, http://dx.doi.org/10.1787/888933617054

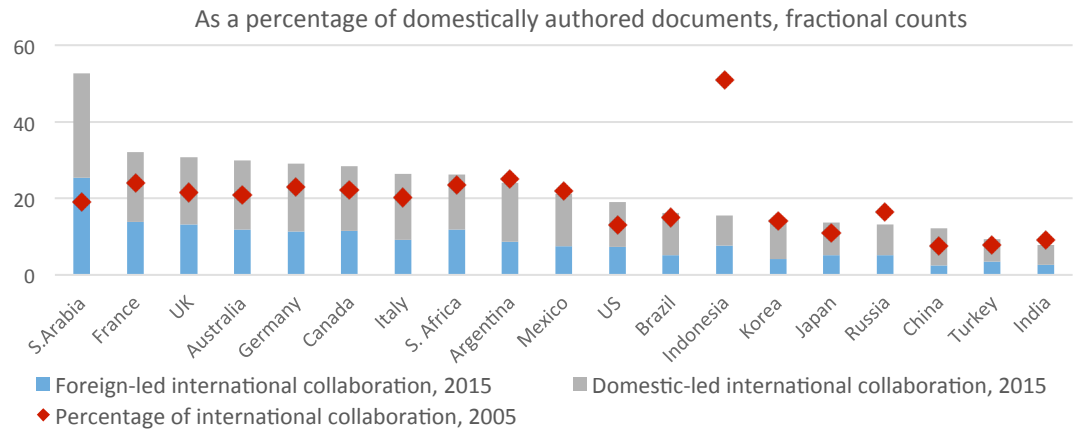
G20 economies are the main resources of the global patent applications. In 2016, 96.4% of total patent applications (91% of non-residents' and 98.4% of residents') was filed in G20 economies. The quadrupling of patent applications by Chinese residents (from 293,066 to 1,204,981) between 2010 and 2016 drove the upsurge in patent applications. Likewise, 88.1% of total patent grants (91.9% of residents' and 82.1% of non-residents') was filed in G20 economies in 2016. China, the United States, and Japan were the most patent granted economies within G20. If we examine patent statistics in detail, it appears that the residents of G20 economies largely dominate all technological fields in terms of granted patents. In computer technology, for example, at least[20] 98.1% of granted patents were filed by the residents of G20 in 2016. That figure was 90% in biotechnology, 88.5% in pharmaceuticals, and 94.8% in micro-structural and nanotechnology. The indicators related to scientific and technical articles, and patents clearly show that the global knowledge generation is largely driven by G20 economies.

OECD's calculations[21] show that international collaboration[22] on scientific studies improved in most of G20 economies between 2005 and 2015, in parallel to the global trend.[23] As shown in Figure 28, the share of internationally co-authored scientific publications in total domestically authored

[20] Data is not available for India for granted patents by technology.
[21] http://dx.doi.org/10.1787/888933618783
[22] "International collaboration is defined as the number of domestically authored publications incorporating institutional affiliations of other countries or economies, expressed as a percentage of all publications attributed to authors with an affiliation in the reference economy. This includes a relatively small proportion of documents by single authors with affiliations in different economies." (OECD STI Scoreboard 2017)
[23] OECD STI Scoreboard 2017

documents increased in most of G20 economies but declined in Indonesia, Russia, India, Argentina, and Mexico in that period.[24]

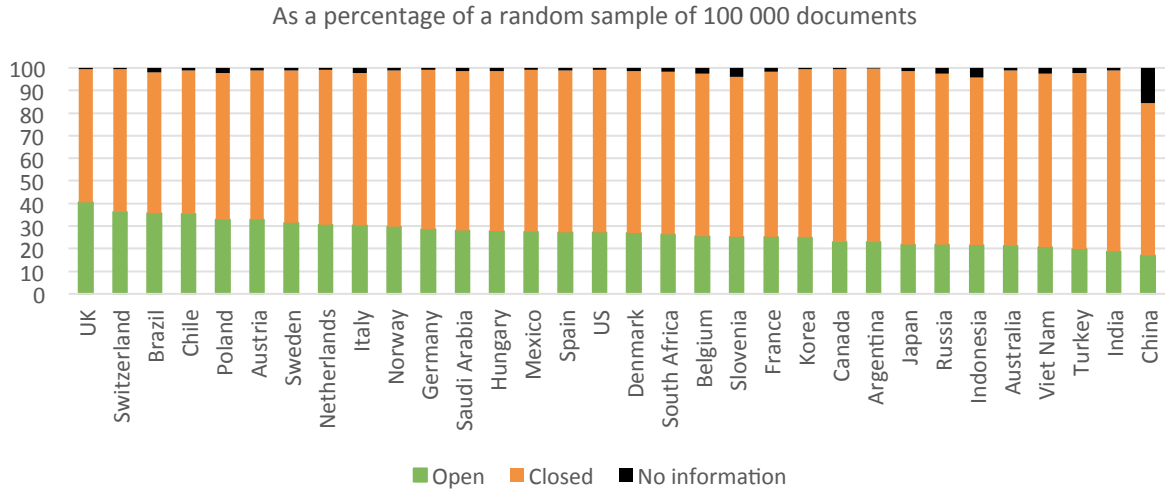
Figure 28: International scientific collaboration, 2005-2015



Source: OECD STI Scoreboard 2017, http://dx.doi.org/10.1787/888933618783

For developing or less developed economies, the access to the scientific knowledge that is generated in relatively more developed countries may be beneficial as well as collaboration in scientific studies. OECD's calculations about the openness level of scientific publications show that there is room for improvement (Figure 29). The United Kingdom had the maximum openness level in scientific documents according to data and it was 40.4% in 2017. The share of open accessible documents was less than 30% in most of G20 economies and developed countries.

Figure 29: Open access of scientific documents in G20 economies and selected countries, 2017



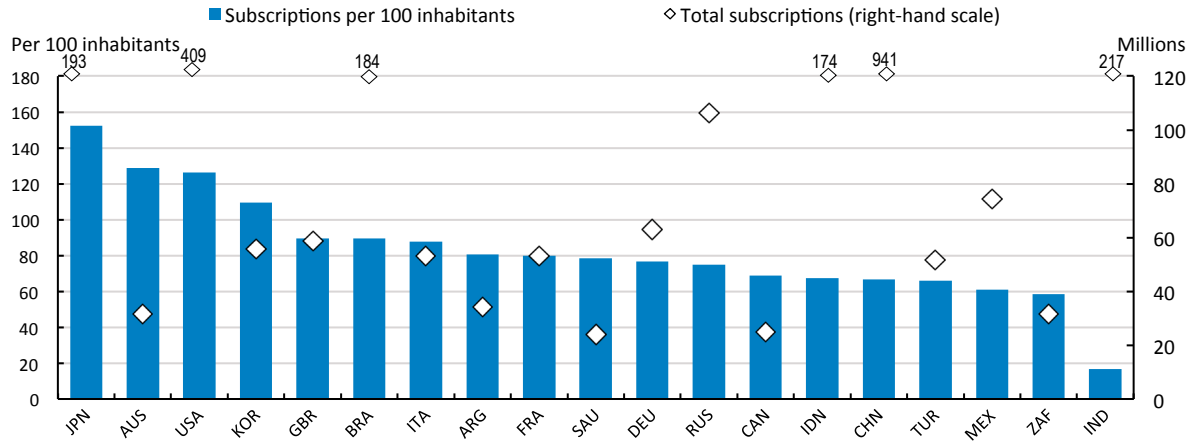
Source: OECD STI Scoreboard 2017, http://dx.doi.org/10.1787/888933618099

[24] There is not any aggregated data for EU countries. But, OECD calculations show that the mentioned ratio on international collaboration was above 20% in 20 out of 26 EU countries and increased in most of these countries.

III. 6 Automation and Robotics Indicators

OECD's Science, Technology and Industry Scoreboard 2017 reports that the share of internet users continued to increase (Figure 30). That was valid for the mobile broadband subscriptions that enhance the access to the services that allow individuals to improve themselves via participating economic and social activities. Data shows that the mobile broadband subscriptions per 100 inhabitants was below the OECD average (99.24) in most of G20 economies in 2016. Although there were gaps among G20 economies regarding that ratio, the rapid increase in the subscriptions (India added almost 100 million broadband subscriptions in 2016, for example) may close those gaps.

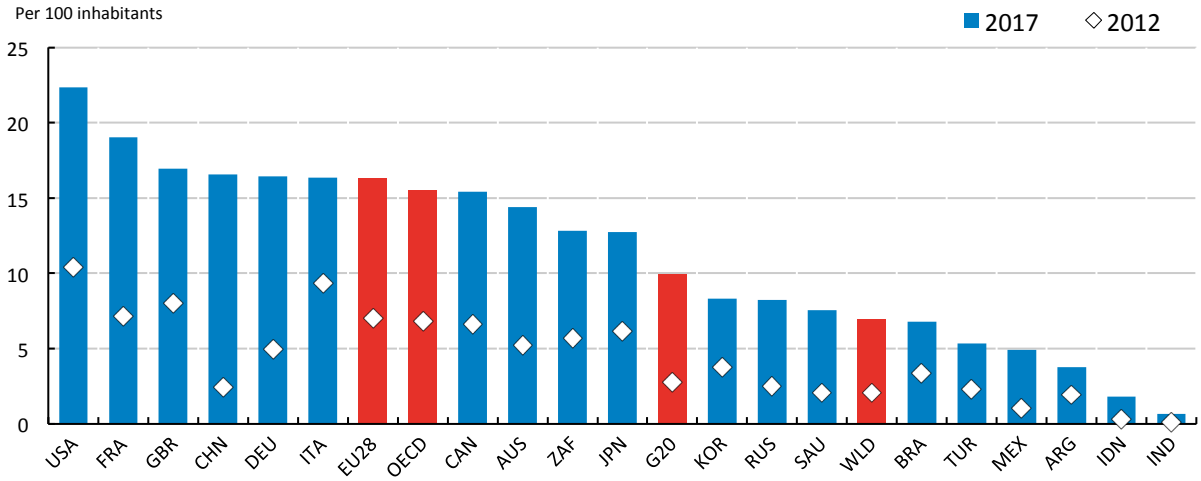
Figure 30: Mobile broadband penetration in G20 economies, 2016



Source: OECD STI Scoreboard 2017, http://dx.doi.org/10.1787/888933616883

Besides the connectivity of individuals to the networks and services, it might be useful to address the status in some technologies that play a central role in the digital revolution. Internet of Things (IoT) is one of these technologies. OECD data shows that the number of SIM cards embedded in machines, which makes machine-to-machine (M2M) communication possible and constitute one part of the underlying infrastructure of IoT, increased between 2012 and 2017. While G20 economies led the world with respect to M2M SIM card penetration, the average for G20 remained below both OECD and EU28 (Figure 31).

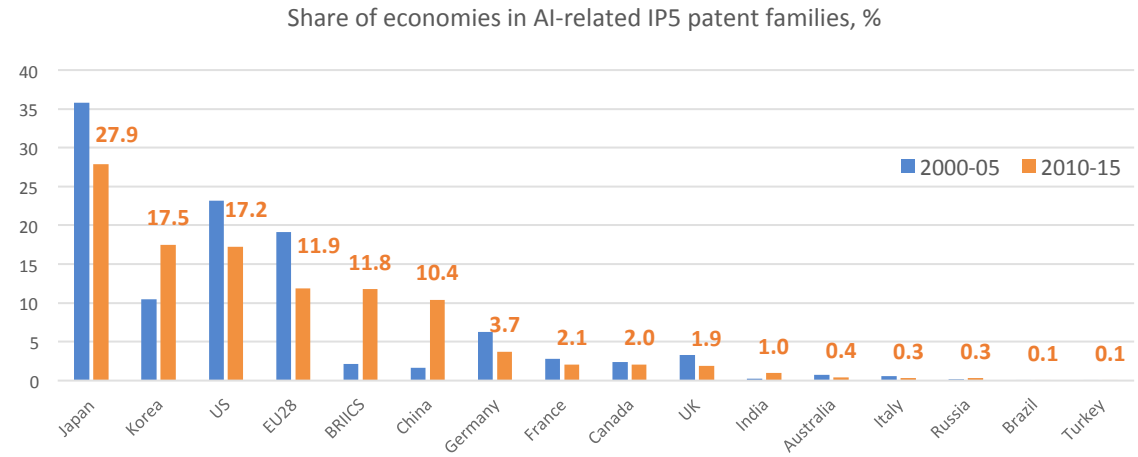
Figure 31: M2M SIM card penetration, OECD, World, and G20 countries, June 2017



Source: OECD STI Scoreboard 2017, http://dx.doi.org/10.1787/888933616902

G20 economies are the main players in artificial intelligence (Figure 32). According to OECD STI Scoreboard 2017, nine of the top ten economies in terms of AI-related patents between 2010 and 2015 were G20 members. Japan, the United States, and Korea produced almost two-third of AI-related patents in that period. The increase in the share of China in AI-related patents might be seen as the reason of the remarkable declines in the shares of developed countries. In contrast to mentioned countries, the shares of Turkey, Brazil, Russia, Italy, and Australia in AI-related patents were below 0.5% in the period of 2010-2015. That indicates the disparities among G20 economies regarding the influence on the new techno-economic paradigm.

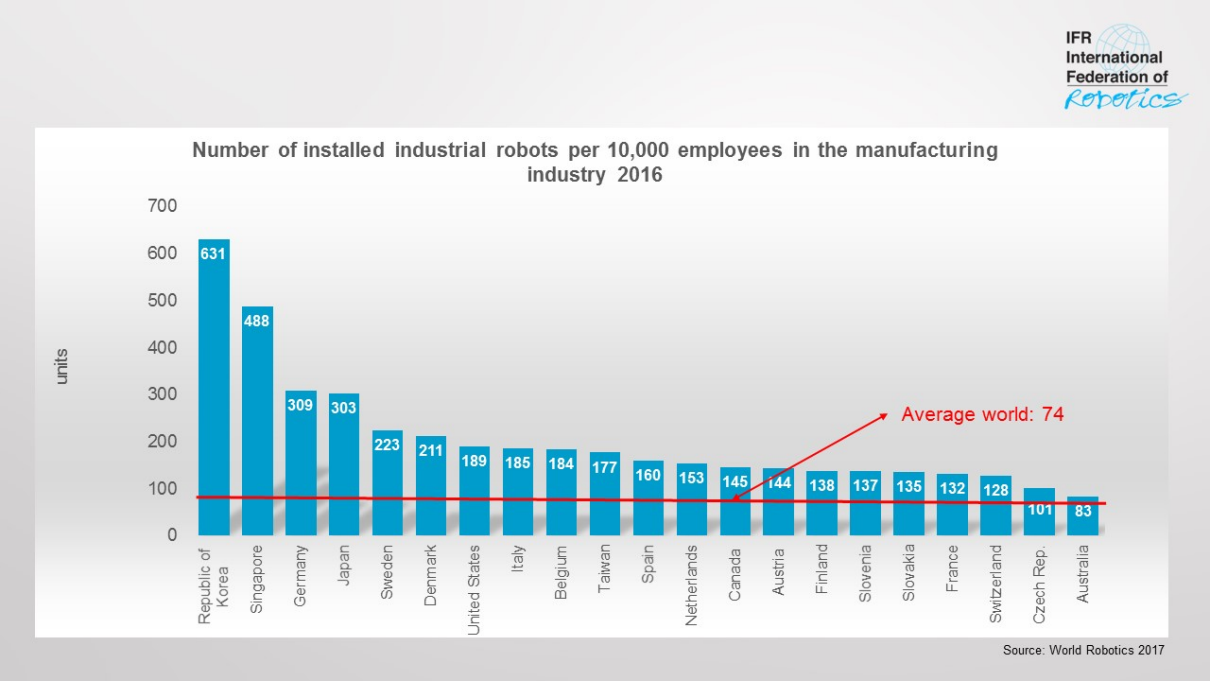
Figure 32: Patents in artificial intelligence (AI) technologies, 2000-15



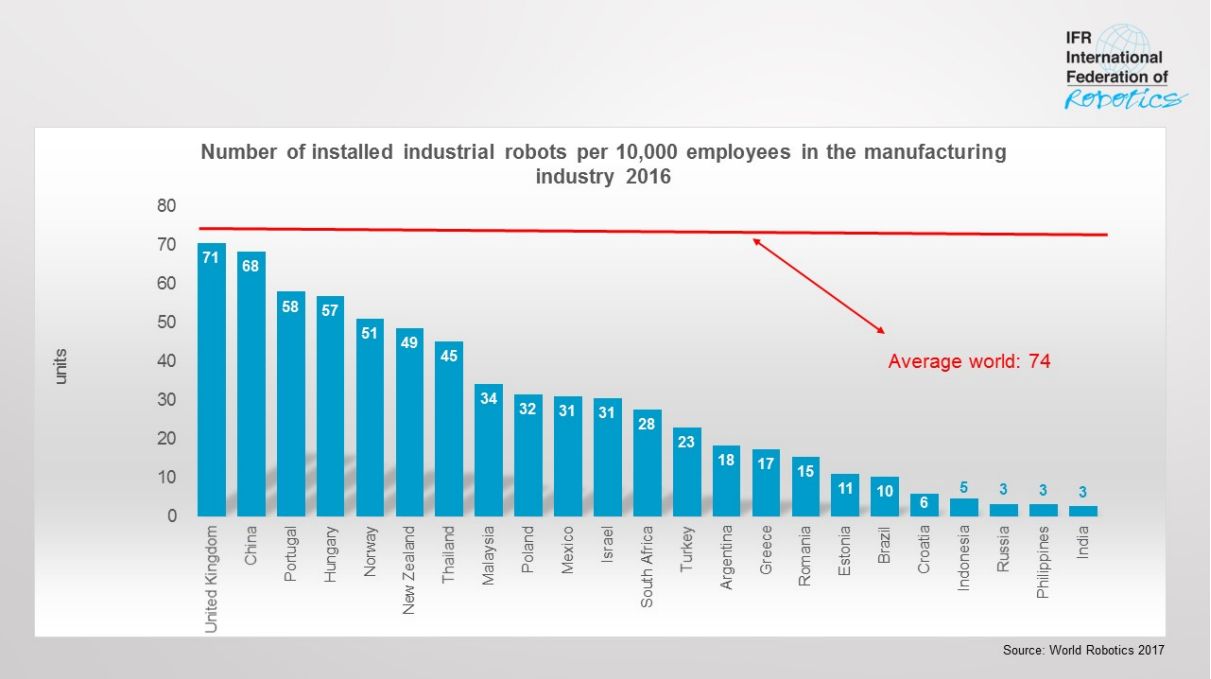
Source: OECD STI Scoreboard 2017, http://dx.doi.org/10.1787/888933616902

The number of Industrial robots is one of the main indicators of the structural transformation in manufacturing. According to the International Federation of Robotics (IFR)[25], robot sales around the world increased by 16% and reached to 294,312 units around the world in 2016. The average number of robot workers also increased from 66 units per 10,000 employment to 74 in the same year. The density of industrial robots in manufacturing varies among G20 economies (Figure 33). The number of installed industrial robots per 10,000 employees was above the world average in Korea, Germany, Japan, the United States, Italy, Canada, France, Australia, and some of EU members. Yet, ten out of G20 economies (the United Kingdom, China, Mexico, South Africa, Turkey, Argentina, Brazil, Indonesia, Russia, and India) remained below the average regarding that ratio according to IFR's data.

Figure 33: Industrial robot density in manufacturing industry in selected economies (2016)



[25] https://ifr.org/



Source: World Robotics 2017, https://ifr.org/free-downloads/

Automation Readiness Index (ARI) 2017 of the Economist Intelligence Unit depicts the status of G20 economies regarding automation and robotics and may provide insights about the future agenda (Table 8). The Index "assesses how well-prepared 25 countries (of which 20 are in G20, including EU countries) are for the challenges and opportunities of intelligent automation".[26] It reveals the disparities among economies regarding automation as well. The Index is composed of three main components that are innovation environment, education policies, and labor market policies. Korea, Germany, Singapore, Japan, and Canada are classified as mature in overall while Turkey, Russia, Argentina, India, Brazil, Saudi Arabia, South Africa, Mexico, and Indonesia remain below the average score. The scores of G20 economies in education and labor market policies articulate the disparities among them. Those scores suggest that G20 economies should need to take required measures and upgrade their skills in order to face the challenges created by automation.

[26] http://www.automationreadiness.eiu.com/#overview

Table 8: Automation Readiness Index 2017

	Overall Score			Innovation Environment			Education Policies			Labor Market Policies	
	Average	*62.13*		*Average*	*69.85*		*Average*	*55.28*		*Average*	*60.38*
1	**Korea**	**91.3**	1	Japan	94.61	1	Korea	87.5	=1	Germany	93.75
2	**Germany**	**89.6**	2	Korea	93.87	2	Estonia	86.11	=1	Singapore	93.75
3	**Singapore**	**87.25**	3	Germany	93.78	3	Singapore	84.72	=1	Korea	93.75
4	**Japan**	**82.57**	4	France	91.26	4	Germany	83.33	4	Japan	87.5
5	**Canada**	**81.76**	5	Singapore	86.52	5	Canada	79.17	5	Canada	84.38
6	**Estonia**	**79.46**	6	UK	84.24	6	France	76.39	6	UK	71.88
7	**France**	**78.93**	7	Australia	83.41	7	Japan	68.06	=7	China	68.75
8	**UK**	**73.07**	8	Canada	83.04	8	UAE	63.89	=7	Estonia	68.75
9	**US**	**71.96**	9	US	83.02	=9	UK	62.5	=7	US	68.75
10	**Australia**	**70.38**	10	China	80.66	=9	US	62.5	=10	Australia	65.63
11	**Italy**	**67.54**	11	Italy	79.09	11	Australia	59.72	=10	Italy	65.63
12	**China**	**67.12**	12	Estonia	78.16	12	Argentina	58.33	12	France	59.38
13	**UAE**	**64.29**	13	Russia	73.25	13	Italy	56.94	=13	Brazil	56.25
14	**Malaysia**	**57.66**	14	UAE	68.7	=14	China	52.78	=13	Turkey	56.25
15	**Turkey**	**53.71**	15	Turkey	67.26	=14	Malaysia	52.78	=13	UAE	56.25
16	**Russia**	**52.49**	16	Malaysia	66.36	16	Colombia	50	=16	India	53.13
17	**Argentina**	**51.74**	17	India	62.27	17	Brazil	47.22	=16	Saudi Arabia	53.13
18	**India**	**47.2**	18	South Africa	57.8	18	Turkey	38.89	18	Malaysia	50
19	**Brazil**	**46.4**	19	Argentina	55.4	19	Mexico	37.5	19	Russia	43.75
20	**Colombia**	**44.65**	20	Saudi Arabia	47.8	20	Russia	36.11	=20	Colombia	40.63
21	**Saudi Arabia**	**41.97**	21	Vietnam	46.6	21	Saudi Arabia	30.56	=20	Vietnam	40.63
22	**South Africa**	**41.04**	22	Mexico	45.52	=22	India	29.17	=22	Indonesia	37.5
23	**Mexico**	**40.71**	23	Indonesia	41.7	=22	South Africa	29.17	=22	Mexico	37.5
24	**Vietnam**	**37.32**	24	Colombia	41.3	24	Vietnam	26.39	=24	Argentina	31.25
25	**Indonesia**	**33.07**	25	Brazil	40.64	25	Indonesia	22.22	=24	South Africa	31.25

Source: http://www.automationreadiness.eiu.com/
Blue: Mature, Green: Developed, Yellow: Emerging, Orange: Nascent

In this section, we concisely summarize socio-economic conditions in G20 economies and present their scientific and technological competence. G20 appears as the largest and most influential economic club of the globe. Furthermore, its impact on the world economy continues to increase in comparison to other economic clubs that consist of relatively more developed countries such as OECD, G7, and EU. Yet, it is difficult to consider G20 as a monolithic actor. There are significant disparities among its members regarding socio-economic development and scientific capability. There have been notable changes within G20 as well. China's progress in every aspect of economic and technological development has increased its influence not just within G20 but also in the world.

International trade and cross-border investments around the world are mainly driven by G20 economies. Those could be considered as important mechanisms for the transfer of knowledge from relatively more developed economies to less developed regions of the world. However, data shows that trade and FDI largely remain as intra-group transactions. That applies to scientific and technologic activities as well. The knowledge generated by G20 economies mainly circulates within the group.

IV. Towards a Global Innovation System?

A robust innovation policy can be treated as a backbone of economic growth and development not only for individual countries but also for country clubs. Ezell et al. (2016) find that some national innovation policies (Finland, Sweden, UK) add value to the global innovation system while some others (India, China, Thailand) may have harmful impact on it.[27] Moreover, there is a close correlation between the success of national policies and contribution to global innovation system. According to Table 9 the highest ranks in terms of net score among the G20 countries belong to UK (3rd), US (10th) and France (11th) while the lowest ranks stand for Argentina (56th), Indonesia (55th) and India (54th) among 56 economies. Thus, it is clear that G20 does not have a significant impact on global innovation in terms of contribution global welfare which calls for an urgent action.

[27] Contributions are mainly measured through taxes, human capital and R&D and technology while the detractions are measured by balkanized production markets, intellectual property production, balkanized consumer markets.

Table 9: Impact on Global Innovation

Rank	Country	Type	Final Score	Contributions Score	Detractions Score
1	Finland	Schumpeterian	15.6	14.1	13.9
2	Sweden	Schumpeterian	14.2	13.9	11.1
3	United Kingdom	Schumpeterian	13.7	13.7	10.4
4	Singapore	Advanced Asian Tiger	12.3	15.0	5.9
5	Netherlands	Schumpeterian	12.1	9.6	12.4
6	Denmark	Schumpeterian	11.6	13.5	6.2
7	Belgium	EU Continentalist	11.4	9.4	11.3
8	Ireland	EU Continentalist	10.9	8.7	11.2
9	Austria	EU Continentalist	10.5	9.2	9.7
10	United States	Adam Smithian	10.5	8.5	10.4
11	France	EU Continentalist	10.2	10.2	7.8
12	Germany	EU Continentalist	9.4	7.0	10.3
13	Norway	EU Continentalist	9.4	7.8	9.2
14	Japan	Advanced Asian Tiger	9.2	11.3	4.3
15	Taiwan	Advanced Asian Tiger	9.2	12.3	3.1
16	Slovenia	EU Up and Comer	9.0	9.2	6.5
17	Portugal	EU Continentalist	8.8	7.5	8.4
18	Estonia	EU Up and Comer	7.3	4.3	9.5
19	Iceland	EU Continentalist	7.1	9.0	3.0
20	Switzerland	EU Continentalist	6.8	8.8	2.5
21	Korea	Advanced Asian Tiger	5.9	14.7	-6.9
22	Australia	Adam Smithian	5.9	4.7	6.0
23	Israel	Advanced Asian Tiger	5.1	8.2	-0.2
24	Spain	EU Continentalist	5.0	3.1	6.3
25	Canada	Adam Smithian	5.0	8.3	-0.5
26	Czech Republic	EU Up and Comer	4.5	2.1	6.5
27	Hungary	EU Up and Comer	4.4	2.9	5.3
28	New Zealand	Adam Smithian	2.9	-1.4	7.9
29	Hong Kong	Advanced Asian Tiger	1.4	-1.8	5.4

30	South Africa	Innovation Follower	0.1	-3.1	4.2
31	Lithuania	EU Up and Comer	-0.2	-3.9	4.7
32	Slovak Republic	EU Up and Comer	-0.8	-6.3	6.7
33	Italy	Innovation Follower	-1.2	-5.8	5.0
34	Latvia	EU Up and Comer	-1.4	-7.7	7.1
35	Poland	EU Up and Comer	-2.4	-6.1	3.0
36	Bulgaria	Innovation Follower	-5.0	-5.0	-3.9
37	Turkey	Innovation Mercantilist	-7.2	-4.8	-8.6
38	Romania	Innovation Follower	-7.7	-9.8	-3.0
39	Malaysia	Innovation Mercantilist	-7.9	-2.5	-13.1
40	Chile	Innovation Follower	-8.1	-10.9	-2.7
41	Brazil	Innovation Mercantilist	-8.3	-3.2	-12.9
42	Russia	Innovation Mercantilist	-8.9	-0.7	-17.4
43	Greece	Innovation Follower	-10.5	-15.4	-1.5
44	China	Innovation Mercantilist	-10.5	0.7	-22.6
45	Colombia	Innovation Follower	-11.0	-15.5	-2.5
46	Costa Rica	Innovation Follower	-11.3	-16.7	-1.5
47	Philippines	Innovation Follower	-12.1	-13.6	-7.3
48	Peru	Innovation Follower	-12.2	-13.6	-7.4
49	Vietnam	Innovation Mercantilist	-12.9	-8.1	-16.2
50	Mexico	Innovation Follower	-13.5	-16.7	-6.1
51	Kenya	Innovation Follower	-13.7	-14.9	-8.8
52	Ukraine	Traditional Mercantilist	-14.6	-14.3	-11.5
53	Thailand	Innovation Mercantilist	-14.8	-5.6	-23.3
54	India	Innovation Mercantilist	-15.5	-8.3	-21.2
55	Indonesia	Traditional Mercantilist	-17.5	-16.1	-15.2
56	Argentina	Traditional Mercantilist	-20.1	-15.8	-21.0

Source: Ezell, et al. (2016)

Moreover, we see a clear fragmentation among the G20 members in terms of the impact of national policies as evident from Figure 34. Except Korea, Canada and China, two groupings are observed. Some members are placed in "above average beneficial policies, below average harmful policies" quadrant such as UK, Germany, France, USA, Australia while the others (Russia, Brazil, Turkey, Mexico, India and Argentina) are on "below average beneficial policies, above average harmful policies" quadrant. It seems that most of the EU member states is on the first quadrant which gives an evidence in favor EU innovation policies that especially accelerated through framework

programmes. Moreover, the success story of EU also proves the possibility of a supranational innovation system.

Figure 34: Countries' Contribution to and Detraction from Global Innovation

Source: Ezell, et al. (2016)

The existing picture directs us to propose a system for creating a win-win strategy towards the club governance of STI policies in G20 where both the members and other countries eventually win. Ezell et al. (2016:12) resemble the situation a prisoner' dilemma yet conclude that *"if humanity is to maximize the global innovation needed to tackle an array of pressing challenges, including developing low-cost clean energy technologies, making breakthroughs in drugs and medical devices, dealing with climate change and resource scarcity, and developing new technologies that can boost productivity, the world will need a fundamentally new approach to supporting development of and trade in innovation based industries."* Except EU, there is no supranational organization dedicates itself to organize a collaborative effort for innovation policies to mitigate global challenges. G20 can be a suitable playground for developing such policies. The global attempt to construct a GIS can be

shaped through the seven pillars of global innovation index[28]. These seven pillars comprises five input (enablers) and two output pillars as follows:

- Institutions,
- Human capital and research,
- Infrastructure,
- Market sophistication,
- Business sophistication.
- Knowledge and technology outputs and
- Creative outputs.

The figures in previous section, in fact, call for a collective action for G20. In some members, there are still problems concerning schooling and STEM education. Second, there is a need for upgrading labor force skills especially for the digital transformation. Third, knowledge-intensive sectors are growing on a global scene in G20 which is an opportunity for knowledge transfer both inside G20 and other economies. Fourth, new markets seem to be emerging for G20 trade, thus transfer of skills to low-income countries and FDI especially in the form of green investments will create long-term opportunities through upgrading both in the supply chain and the quality of demand. Finally, there is an urgent intervention for a consensus on trade policies and keeping global markets away from innovation mercantilism.

These measures calls for a systemic action towards a GIS in the context of seven pillars listed above since most of the global challenges cannot be mitigated by either regional and/or national action. The governance structure can be transferred from successful applications of EU towards more innovative outputs for global challenges and commercialization of knowledge. The steps can be summarized as follows:

- Establishment of fund to support studies of GIS
- Formation of a working committee for studies of GIS
- Launch of a steering committee for studies of GIS
- Prioritization for global socio-economic challenges
- Expert panels toward policy making for prioritized problems to determine policy aims, policy recommendations and policy tools
- Common financial mechanism or policy implementation
- Collaborative project financing
- Evaluation and monitoring

[28] https://www.globalinnovationindex.org/about-gii

Through these actions not only G20 members yet the actors in the least developed countries can be connected to global knowledge and innovation pipelines. Given the existing conditions of income and development disparities on the globe, catching-up still seems to be possible. The sustainable global growth involves the broadening of the global frontier through a global club governance. However, the governance mechanism should not only be based on a top-down approach yet through an interaction with UN agencies and other countries with a bottom-up approach. In order to tackle with the global challenges the emerging GIS may be the first step towards a transformation of the existing global economic system as named by Brown and Levey (2015) a new Golden Age of capitalist era. For instance, The International Technology Bank, which was recently established in Turkey "to improve the utilization of scientific and technological solutions in the world's poorest countries and promote the integration of least developed countries into the global knowledge-based economy"[29], could act as an intermediate for the knowledge exchange between G20 members and developing and least developed countries. The actors, including firms, interacting with each other in GIS will attain higher innovative performance than the actors interacting in their national boundaries. The output of these innovative activities can be treated as global public goods (Andersen et al., 2007). The existence of a wide range of global public goods will definitely increase the welfare of humanity. The challenge here is to create the global governance mechanism to increase the supply of global public goods. Such a global governance structure would construct a more level playing field for all involved actors (Schmidt and Huenteler, 2016) and could also be used to mitigate trade disputes and reduce overcapacities while speeding up policy learning and transition dynamics in various parts of the world (Binz and Truffer, 2017) by G20 labelled as *innovation elites*.

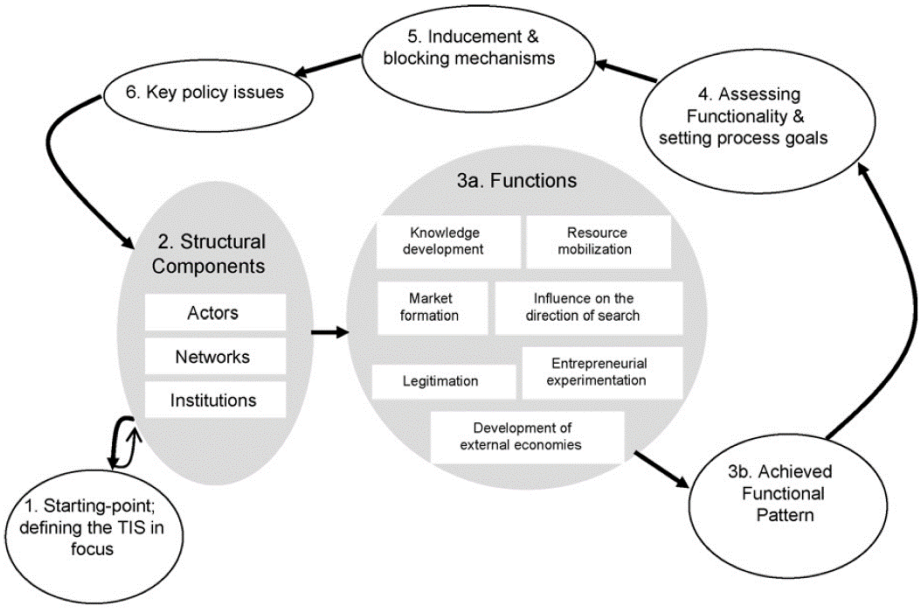
V. Concluding Remarks

This study is an intellectual attempt of how G20 facilitates GIS through a club governance structure. In fact, G20 has recently established various working groups such as T20, B20, C20, W20. However, these working groups are loosely defined and G20 needs a systemic approach towards GIS and, in turn, for a wealthier globe. The major problem in this process is the existence of complex spaces in which global innovation networks and national systems are complicated to govern. However, with small starting steps and well-defined global challenges, the paper shows that club governance of a GIS is possible through the transformation of existing global socio-technical system. From an evolutionary perspective, in order to mitigate the existing global challenges, this transformation seems to be inevitable for the prosperous future of humanity. The design of GIS necessitates various starting postulates. First, various studies (Castellani and Zanfei, 2006; Dicken, 2007; Redlich et al., 2014; Barnard and Chaminade, 2017; Öberg and Alexander, 2018) show that the openness of an

[29] http://unohrlls.org/technologybank/

innovation system brings about higher success with an ever increasing update of the knowledge base. Second, the functional dynamics of GIS should be built upon a participatory bottom-up decision-making process. Actors, networks and institutions should be tied up to functions as proposed by Oltander and Prez Vico, 2005; Hekkert et al., 2007; Bergek et al., 2008; and Hekkert et al., 2011). For a detailed visualization see Figure 35 below. The figure defines the conceptual framework of the steps discussed in the previous section.

Figure 35: Functional Dynamics of an Innovation System



Source: Oltander and Prez Vico, 2005

Third, the GIS should be based upon consensus-building approach rather than conflict resolution. The actors of the system should agree on the global problems where the minimal number of disputes exist on the globe such as the challenges that threat the humanity as a whole. Finally, it can be claimed that such an approach is inevitable and needs urgent action considering the existing global challenges and challenges associated with the multilateralism.

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