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RESEARCH, DEVELOPMENT AND INNOVATION IN BUSINESS ENTERPRISES: EXPERIENCE FROM EGYPT*

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Abstract. This paper addresses the linkages between research and development (R&D) and innovation on the one hand and the socioeconomic impact of research, development and innovation (RDI) on the other hand. More specifically, the paper suggests a two-stage methodology directed to analyse the performance of RDI in business enterprises and assess their development impact. A conceptual four-dimensional model and an integrated analytical framework were developed. This approach is complemented by the development of a statistical survey mainly designed to generate appropriate indicators for analysing the vital role of RDI in business enterprises. The survey results revealed several analytical points as well as specific imbalances of RDI system in business enterprises that need to be addressed by policymakers. Furthermore, the analytical results stress the need for Egyptian business enterprises to enhance and diversify their cooperation with other RDI-producing institutions to benefit from comparative advantages and improve the quality of RDI outputs.

Keywords: Research; Development and Innovation (RDI); Business Enterprises; conceptual model of RDI; Developmental Impact of RDI

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JEL Classifications: O3. 055

1. Introduction

Research and development (R&D) comprise "creative work undertaken on a systematic basis to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications" (OECD, 2015). Innovation, on the other hand, is viewed as "creative activity leading to the development of new product or process which differs significantly from the product previously delivered to consumers, or the process previously used by the company or the industry" (OECD/Eurostat, 2018). Based on the

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above definitions and rationale, scientific research, development, and innovation systems (RDI) represent a central issue in knowledge generation, dissemination and application processes in support of development.

Furthermore, innovative products and processes introduce new or significantly improved goods and services to be used in the product markets. They, therefore, represent an important factor supporting the acceleration of economic growth and the achievement of sustainable development of a country. Given the recent advancements in knowledge markets and the surge in intelligent digital technologies associated with the fourth industrial revolution, scientific research and innovation became a cornerstone of the transformation of knowledge societies and their economies in the twenty-first century.

Given its observed impact on transforming countries into a knowledge society and economy, and its recent increasing role in keeping pace with the fourth industrial revolution and its digital transformation trend, the RDI conceptual model has witnessed sensible changes and acquired new features. RDI became today an integral part of most sustainable development national strategies. These recent developments required changes in the original design and structure of RDI analysis and contribution to the production sectors.

2. Review of literature

Over the last ten years, the literature review on the topic of research, development and innovation has been a frequent research method. Several topics have been raised and discussed: Harmonic innovation as a virtuous evolution for the community development (Zangara et al., 2023), innovation magnitude of manufacturing industry (Rezk et al., 2016), or Business model innovation themes of emerging market enterprises (Luo et al., 2022). Similarly, a systematic literature review on the impact of R&D in industries is extensive, covering a wide range of topics: study the significant R&D investments in the presence of a positive and lagged effect of R&D investments in the high-tech industry (Chen et al., 2019), The Impact of R&D expenditure on firm performance in manufacturing industry (Öztürk & Zeren, 2015), The Impact of Government Subsidies on Private R&D and Firm Performance (Jin et al., 2018) among others.

Despite the numerous studies of the performance of RDI in business enterprises (Beld, 2014, Yigitcanlar et al., 2018, Kim et al., 2014), existing evidence are inconclusive to find specific ways for assess of development impact. Prior studies have explored the interrelationship between R&D investment, financial leverage, and a firm's R&D innovation success (O'Connell et al., 2022), or examition the drivers of university–firm R&D collaboration while at the same time assessing the determinants of innovation in the industry by analysing firm R&D collaborations with partners different from universities (Maietta, 2015) or comparing the impact of two policy instruments that may induce firms in developing countries to invest in R&D activities (Fernández-Sastre & Montalvo-Quizhpi, 2019) or investigates the mediating role of innovation performance in the effects of R&D intensity and R&D internationalization on firm performance (Leung & Sharma, 2021). Thus, a more approach that assess the impact of RDI on development of industry and their relation to economy is needed.

Management and economics, two areas close to science, are directly related to the study of innovation. The first seeks to understand the internal aspects of innovation, while the second aims to understand the implications of its evolution within companies (Kemp et al., 2003, Taques et al., 2021).

As shown in figure (1), the four-dimensional model represents approaches to analyse RDI performance and evaluate its impact on knowledge transformation in a country. The dimensions include; i) Inputs for producing RDI, ii) Alternative RDI output categories, iii) RDI pertaining to a specific sector in the production sphere of the national economy, based on the international standard industrial classification (ISIC) scheme (UNDESA, 2008) and iv) Modes of RDI cooperation between business enterprises and other national institutions, mainly RDI

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producing institutions (such as universities and research centres), industrial clusters for innovation, and other social and manufacturing societies (UNDP/MBRF, 2021).

Regarding the "first category", RDI as a production function uses inputs related to gross spending on RDI, RDI human capital and sources of financing its activities. Examples of these input measures include spending per researcher, gross expenditure on RDI as a per cent of gross domestic product (GDP), number of researchers per thousand labour force, gross expenditure on research and development (GERD) financed by business enterprises (Khorshid, 2015, 2018).

Innovation in the production activities or business sector (as part of total RDI) is analysed in detail in Oslo manuals (OECD/ Eurostat, 2018). The experience has shown that innovation generated by R&D institutions and business enterprises represents the most significant part of its outputs. Finally, RDI, in general and innovation, in particular, are also produced outside the research and development centres, and the production sphere of the economy. This generally happens with societies characterised by a high percentage of creative, highly skilled and educated labour. This innovation sub-model is entitled "societal innovation". As a source of producing innovation, these institutions require a modern technology environment that coop with the knowledge era and the fourth industrial revolution of the twenty-one century and a favourable enabling economic and social setting(UNDP 2016, 2017, Cornell University, INSEAD and WIPO, 2020).

The “second dimension of RDI” conceptual framework shown in figure (1) depends on the nature and diversified structure of its expected outputs and development impact. Here, we can identify three categories of outputs; the first is concerned with R&D outputs such as publication counts, citation statistics, quality of research outcomes and patents by origin. The second category is related to knowledge impact and diffusion. This second category includes intellectual property receipts, the growth rate of production output per labour, and computer software spending on R&D. Finally, the last category of this RDI output dimension includes creative and cultural goods and services, intangible assets and online creativity. It is worth noting here that this second dimension reflects to a great extent the modern view of evaluating the impact of RDI, in the twenty-one century (Cornell University, INSEAD and WIPO, 2020).

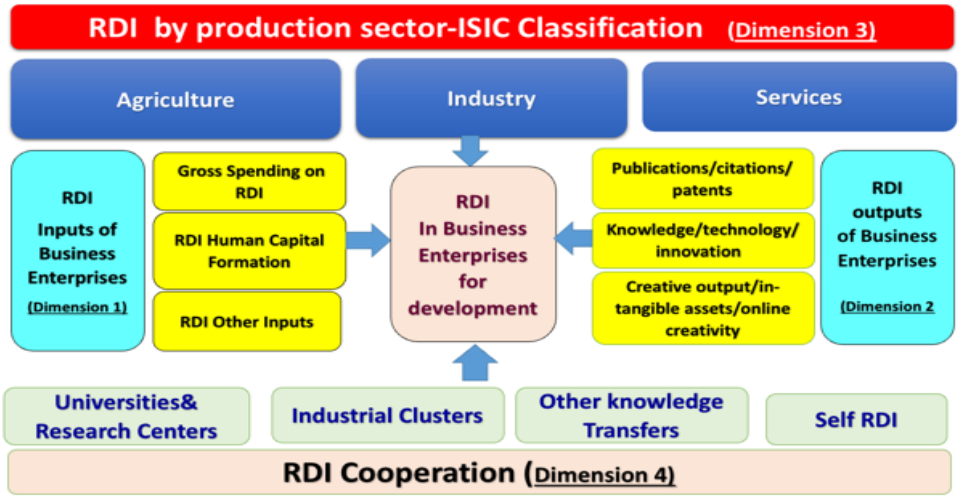

Figure 1. The Four-dimension conceptual model for assessing RDI in Industrial Enterprises

Source: the authors

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As shown in figure (1), research and innovation can be classified similarly according to the production sector of the economy. This "third dimension of RDI" addresses development and innovation in a selected economic sector or production activity based on ISIC classification scheme. Despite the various breakdowns of economic activity, the most used sectoral division in RDI-based research identifies private and public industrial activities, general government sectors, households sector and non-profit institutions serving the households sector (NPISHS). For our study, ISIC disaggregation is determined by the number of production sectors covered by our statistical survey. The elements of the study concentrated on our application to the establishments pertaining to the economic activity in the governorates of Greater Cairo.

The last and "fourth dimension" of RDI conceptual model is classified by the research cooperation schemes or agreements. These classifications include four categories of research and innovation projects. The first is explained by RDI projects executed jointly by the business enterprise and research-producing institutions such as universities, research centres or scientific networks. The second category concerns RDI organised by industrial clusters composed of products and services enterprises (Khorshid, 2022, OECD, 2019). The third category addresses research projects carried out by the business enterprise that benefits from alternative knowledge transfer channels such as; intellectual property rights, research mobility of university professors to support enterprises on part-time bases, engagement of new highly skilled and educated graduates, published scientific research, the outcome of scientific conferences, virtual research networks and facility sharing with universities and research centres. Finally, the last category, assumes that the business enterprise will carry out the desired RDI activities on its own or without external support.

3. Methodology

3.1. Survey design and sample selection

The statistical survey is designed considering the above conceptual model for analysing RDI impact on the performance and functioning of business enterprises in Egypt, as well as the economic structure and geographic nature of the governorates of Great Cairo. The breakdown of various manufacturing sectors and enterprises of the sample was based on three main criteria; i) the rules governing the International Standard Industrial Classification of All Economic Activities (Revision 4) issued by the United Nations - Department of Economic and Social Affairs (UNDESA, 2008), ii) the number of workers in the production enterprise, as well as, iii) the sectoral contribution of the economic sector to GDP. Two constraints affected the sample selection process. The first constraint is that the number of employees should not be less than 25 workers. The second constraint was based on ranking the relative importance of each economic activity with respect to its contribution to the gross domestic product or GDP (self-financing RDI Projects).

The Centre for Statistical Surveys of the Faculty of Economics and Political Science at Cairo University was responsible for surveying to assess the role of research, development and innovation in the business enterprises of the Egyptian economy, according to the scientific rules and methodological methods used in this regard (OECD / Eurostat, 2018 and UNESCO/UIS, 2014). Data were collected in 2018 from (441) establishments in nine production sectors: foodstuffs, textiles and apparel, chemicals, pharmaceutical and pharmaceuticals, computers, electronic and optical products, electrical equipment, information and communication, finance, insurance, accounting and legal activities, and activities pertaining to the field of human health.

3.2. Specific Features of the Sample

Given the above criteria for the design and representativity of the sample, table (1) shows the number of business enterprises allocated to different production sectors based on ISIC classification. The sample structure shows that the textile and clothing activity occupied the largest share of the selected business enterprises, with a number reaching (130) establishments and (29.5) per cent of the sample size. The activity of human health came in

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second place with (97) establishments and (22) per cent, followed by the establishment pertaining to the food manufacturing production sector with (86) enterprises and (19.5) per cent. With respect to the manufacturing of computers, electronic and optical manufacturing sector, the sample size was at most (5) establishments with (1.1) per cent of the sample. Table (2) shows the distribution of the sales volume in million EGP of the sampled establishments by economic activity. (Ismail et al., 2020; UNESCO Institute of Statistics, 2014)

Table 1. Distribution of the selected sample establishments according to the economic activity

Production activities	No. of Establishments
Manufacture of food products	86
Manufacture of textiles and apparel	130
Manufacture of chemical materials and products	62
Manufacture of pharmaceutical and pharmaceutical products	12
Manufacture of computers and electronic and optical products	5
Manufacture of electrical equipment	18
Information and Communication (Computer Programming - Information Services)	6
Financial activities, insurance activities, legal activities, and accounting activities	25
Activities in the field of human health	97
Total number of establishments	441

Source: Survey results.

Table 2. Distribution of the selected establishments according to the volume of sales (in Million EGP)

	Activities									
	Health activities	Financial, insurance and accounting activities	Computers, electronic and optical products	Electrical Equipment	Information and communications	Textiles and apparel	Pharmaceuticals and pharmaceuticals	Food	Chemicals	Grand Total
Less than 50 thousand	1.04%	4.00%	20.00%			6.25%		2.50%		2.90%
500-50 thousand	30.21%	56.00%			16.67%	20.54%		8.75%	3.23%	18.36%
500 thousand - 2 million	52.08%	28.00%	40.00%	31.25%	50.00%	26.79%	41.67%	28.75%	38.71%	35.99%
10-2 million	12.50%	12.00%	20.00%	25.00%	33.33%	22.32%	41.67%	26.25%	29.03%	21.98%
More than 10 million	4.17%		20.00%	43.75%		24.11%	16.67%	33.75%	29.03%	20.77%
Grand Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.01%	100.01%	100.00%	100.00%	100.00%

Source: Survey results

4. Analytical Results

Analytical results based on the statistical survey are organised in light of the dimensions of RDI conceptual model explained in section (1) of the paper. We begin with the analysis of RDI inputs (Dimension 1) and then with RDI outputs (Dimension 2), taking into consideration RDI-specific characteristics and the nature of the production sector in Egypt (Dimension 3). Finally, following dimension 4, research cooperation between business enterprises and other domestic institutions (universities, research centres, etc.) is assessed. As we have explained in the above sections, sample size consists of (441) establishments collected from the governorates of Greater Cairo and grouped into nine economic activities which are foodstuffs, textiles and clothing, chemicals, pharmaceutical and pharmaceutical materials, computers, electronic and optical products, electrical equipment, information and

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communication, financial and insurance services, accounting, legal services and human health activities.(Ismail et al., 2020; Khorshid, 2022).

4.1. Dimension 1: Research, development and innovation inputs

Based on the developed RDI conceptual model, dimension 1 emerges from treating RDI as a production function, with inputs to be provided by business enterprises and partly imported from other institutions, and outputs ensuring the desired quality and satisfying market demand for research and innovation services. Inputs of RDI are broadly composed of gross spending on the production process, cost of human research capital, and other expenditure items (such as the purchase of industrial designs, patents and property income).

RDI Human Capital

Figure (2) summarises the human capital composition, including research and development workers. Based on the survey results, the total number of employees in the business enterprises is computed as (59,463) persons. The research, development and innovation workforce reaches (4,292) employees, with an estimated share reaching (7.2) per cent of the total labour force, on average, across all economic sectors. These RDI employees are generally characterised by being highly educated, skilled and competent. This percentage share is relatively low compared to advanced industrial and developing countries. It captures an essential structural imbalance in Egypt's labour market. Based on recent analytical indicators of the Egyptian science, technology and innovation observatory (ESTIO) of the academy of scientific research and technology (ASRT) in (2019), (60) per cent of research and development human capital is working in the higher education sector, (32) per cent of researchers are engaged in the public research centre of the government sector. Private Business enterprises and other non-government non-profit institutions are left with only (6 to 8) per cent of the aggregate research labour force. It is worth noting that the percentage share of researchers in the business sector of advanced industrial countries such as Japan, the USA, and Germany represent 79, 70 and 60 per cent, respectively.

Furthermore, Egypt occupies the (58) country rank in the indicator measuring the percentage share of researchers working in production enterprises in the global knowledge index (GKI) produced by UNDP and Mohamed Ben. Rashid knowledge association (UNDP, 2021), with a performance measure, computed only as (19.6) per cent. Finally, research workers in Egypt per million persons account for (1,500) persons, whereas Lebanon, Tunis, and Morocco realised (3,400, 3,100 and 2,200) persons per million inhabitants, respectively.

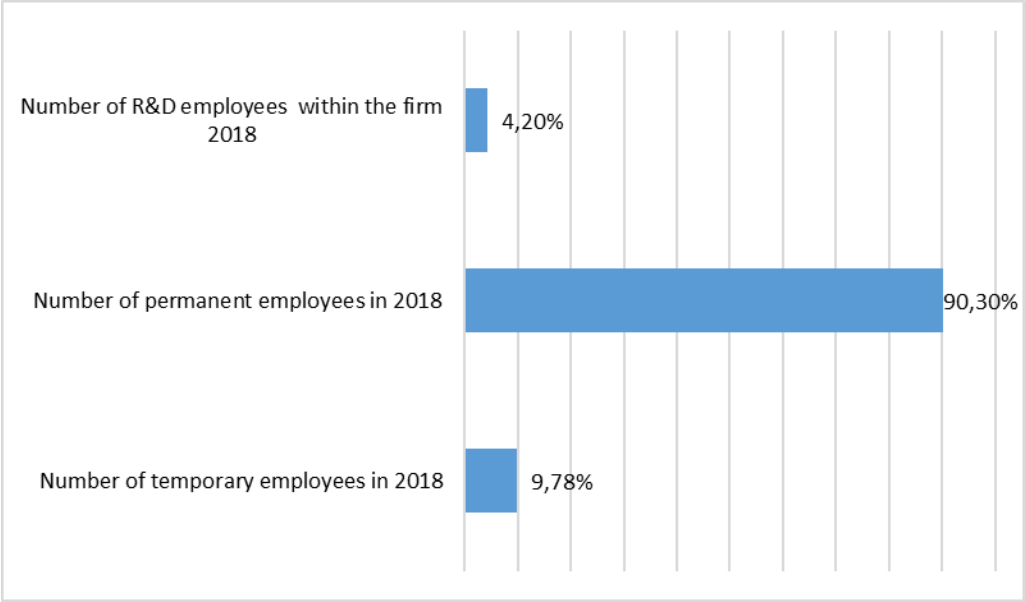

Figure 2. Distribution of employees between RDI and other activities (%)

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Spending on Research, Development and Innovation

Figure (3) shows the breakdown of spending on RDI. It includes three expenditure types; operating costs, investment spending on physical assets, and investment on intangible assets. Operating costs include compensation of RDI employees and intermediate consumption. Investments in physical assets comprise purchases of computer equipment and measurement instruments and the cost of building and construction. The remaining cost items concern investment in intangible assets. In the knowledge era of the current century, intangible assets represent a considerable part of the total production assets of a manufacturing enterprise. In most developed countries with the advanced industrial sector and high levels of technology inputs, intangible assets account for around (40 to 50) per cent of their total production assets (Khorshid et al., 2019; UNDP, 2021). Intangible assets are divided into three categories: i) informatics and database systems, ii) intellectual property products and iii) Economic competencies such as training and re-orientation activities, production of trademarks, marketing systems and management and organisational innovations. The essential component of intangible assets in the twenty-first century is intellectual property rights. These assets are considerably dependent on innovation initiatives and activities. They include four sub-components: intellectual property income, research and development, patents and industrial designs, and creative and cultural products. Not here that the new trends in estimating innovation reflected in the global innovation index (WIPO, 2021) consider creative and cultural outputs as part of the innovation composite index.

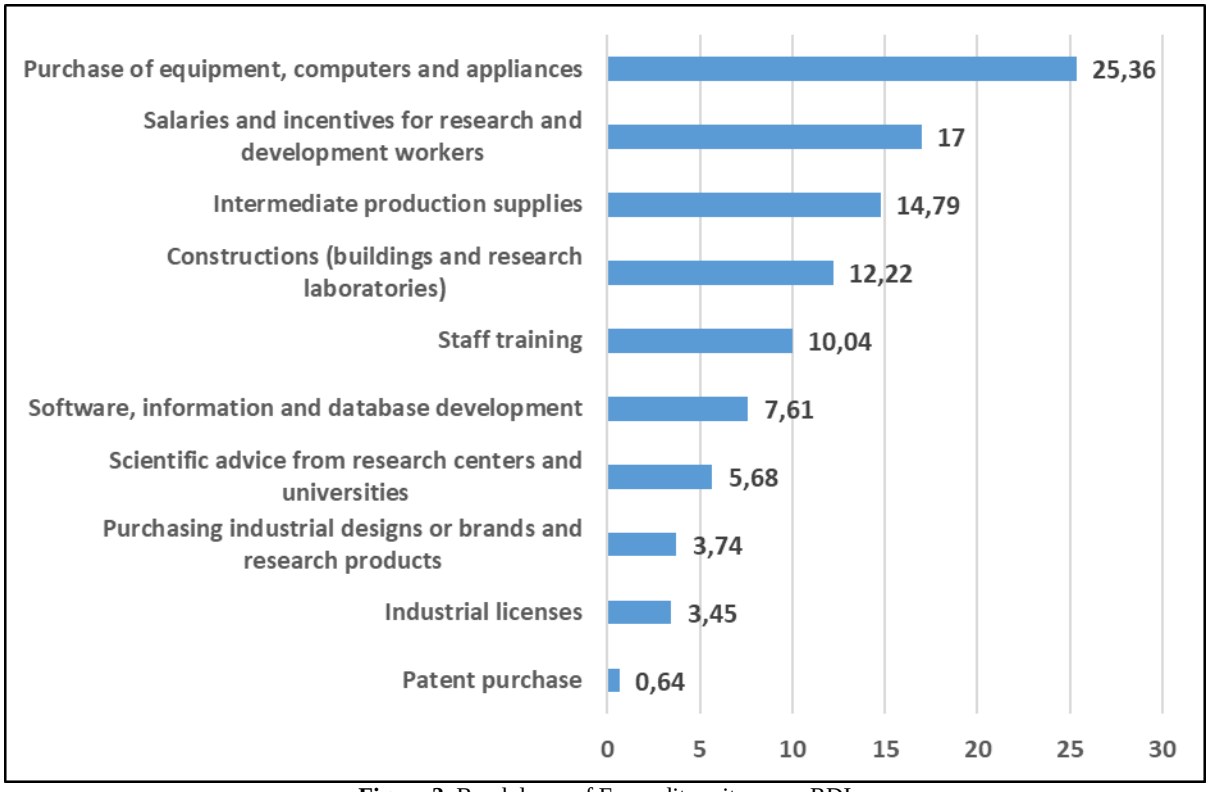

Figure 3. Breakdown of Expenditure items on RDI

The spending structure of the business enterprise represented in the collected sample reflects a number of analytical points. Investment in intangible assets to produce innovative goods and services and significantly improve manufacturing, managerial and marketing operations is relatively limited, except for staff training, which accounts for (12) per cent of total spending. Spending on R&D provided by research centres and universities is less than (6%). Purchase or acquisition of all intangible assets, such as informatics and database developments, research consultation, and purchases of industrial designs, trademarks, and patents, account only for about (15)

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per cent of the gross RDI expenditure of the firm. The most significant part of spending on RDI are purchases of computers and other equipment (25%), compensations of the research labour force (17%) and intermediate inputs (15%).

4.2. Dimension 2: Research, Development and Innovation outputs

Structure of Outputs:

Based on the conceptual model described in section 1, RDI outputs of industrial corporations can be evaluated on three fronts. The first concerns publications, citations and patents, which are produced jointly by universities, research centres and business enterprises. The second output front is more oriented towards knowledge and technology outputs. Finally, the last output front deals mainly with innovation, including creative and cultural outputs, intangible assets and online creativity (OECD 2008, WIPO 2021; World Bank 2022). Figure (4) summarises the average number of RDI outputs from Egypt's business enterprises based on the survey results for 2016 and 2018.

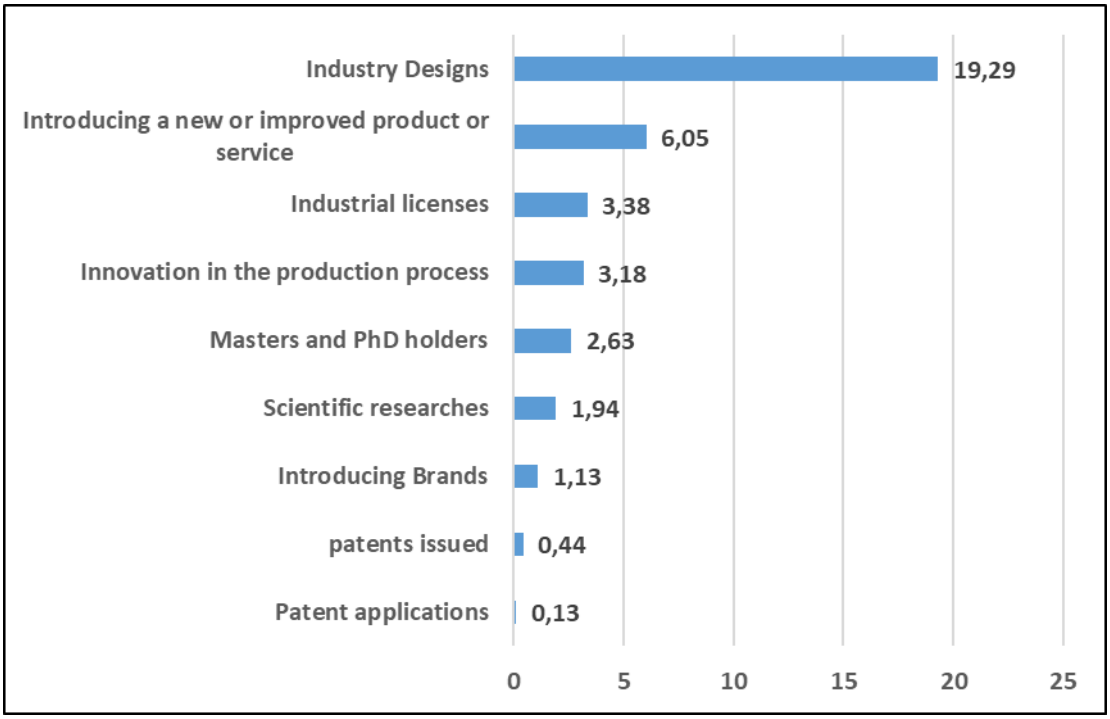

Figure 4. Average RDI outputs of Egyptian business enterprises

The survey results stress that the highest output type is industrial designs as a component of the enterprise's intangible assets. Their average number account for (19.29) designs across the business sectors covered by the statistical survey. The second-highest average number of outputs are new (or significantly improved) commodities or services representing part of the enterprise's innovation activities. This innovative output type is computed as (6.05) units per the surveyed period. The third RDI output is the acquisition of the licensed property income and the innovation of the production process, with average numbers accounting for (3.38) and (3.18), respectively. Other RDI output types, such as published research, patents or commercial marks, are extremely limited. These results stress finally the need to enhance RDI outputs of business enterprises and diversify the scope of their outputs.

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Economic Return:
Despite the modest ability of the sampled establishments to innovate, export and produce intangible assets, investment in research, development and innovation has achieved a positive economic return. Figure (5) captures the economic impact of RDI activities on the performance of the sampled business enterprises. The most important economic impact of RDI is the considerable increase in the sales of goods and services, which account for (39) per cent on average. An increase in the enterprise's production capacity can be observed, which reaches (32) per cent on average.

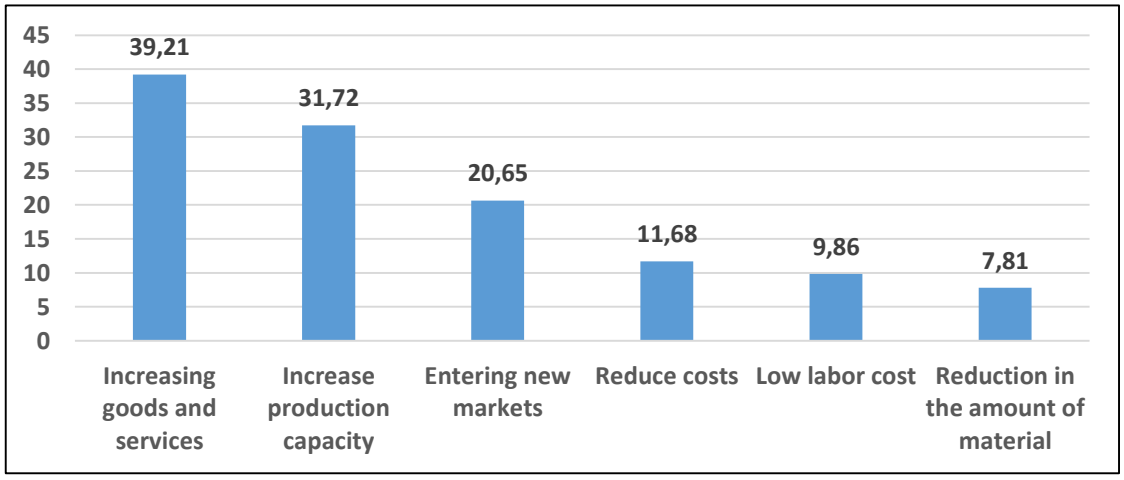

Figure 5. Economic return of RDI on business enterprises (%)

The penetration into new commodity markets represents the third RDI economic effect, with an increase of (21) per cent. Finally, the impact on reducing production and labour costs is considerably less than the increase in sales volume (Pradeep et al., 2017).

RDI Barriers:
In figure (6), barriers facing the business enterprises to carry out RDI activities and benefit from their positive impact on productivity are summarised. Based on the results of the survey, the financing needs represent the most important barrier to carrying out RDI activities in business enterprises with a probability of (39) per cent, followed by the no need for its adoption, with an associated probability of about (24) per cent. This second result can also be interpreted by the fact that managers may not be generally convinced of the benefits of applying RDI in business enterprises. Economic market fluctuations and volatility are a third barrier to carrying out RDI in business enterprises, with a relative probability of (16.5) per cent. Another significant barrier to RDI is the need for qualified researchers or knowledge workers (with 6.1 per cent) and structural distortions created by the increasing number of business enterprises in the economy's informal sector.

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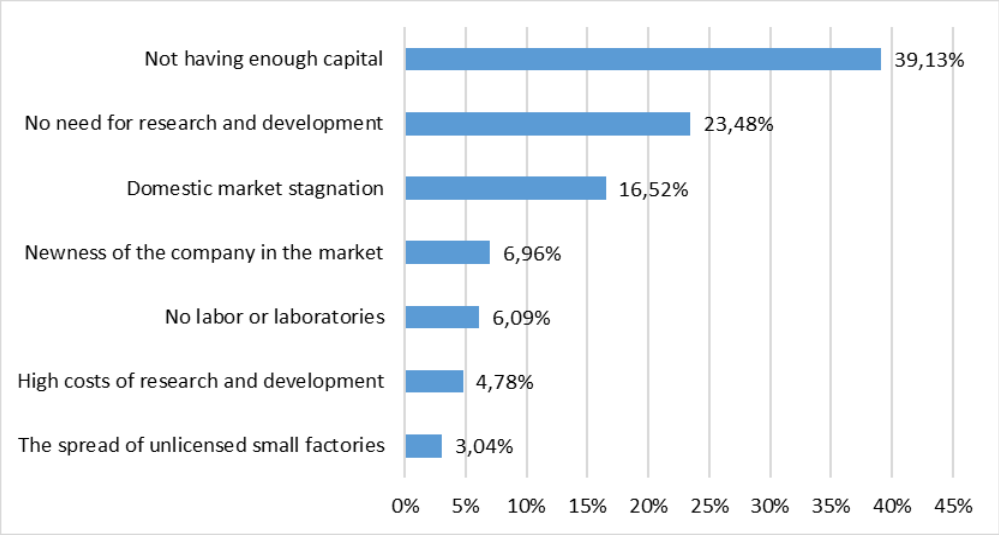

Figure 6. Barriers affecting RDI performance (%)

4.3. Dimension 3: Breakdown by Production Activity

In this section, RDI performance in different production sectors is assessed to identify the industries that rely more on RDI to enhance the productivity and competitiveness of their outputs and the need for other sectors to apply more research and experimental development as well as innovation initiatives. Table (7) records higher education graduates as a per cent of total employees by production sector. Given that researchers generally have a higher education degree, they can represent a proxy for the percentage share of RDI workers. Results from the survey stress the superiority of financial, insurance, accounting and legal services concerning the percentage share of higher education graduates, which account for (83) per cent of their workers. Information, communication, and health care are the second and third sectors concerning the percentage of higher education graduates, with (67) and (63) per cent, respectively. Other sectors, such as Pharmacy and medicines, as well as computers and electronic products, include (45) and (40) per cent of their employees with higher education degrees.

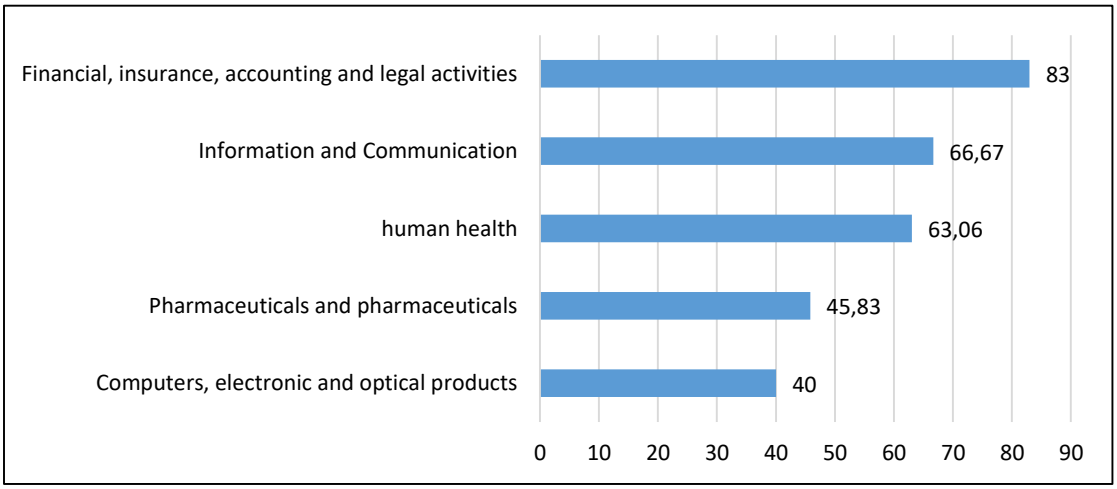

Figure 7. Per cent of higher education graduates in total employees by sector

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Figure (8) illustrates gross expenditure on R&D activities as a per cent of sales in business enterprises by production sector. The information and Communication sector comes on top of the list with a share reaching (20) per cent. Given its responsibility to implement Egypt's national digital transformation strategy, the sector needs relatively advanced research and innovation activities. Furthermore, the financial, insurance and juridical sectors and health care system follow with an expenditure share varying from (19 to 20) per cent. The remaining sectors' spending patterns vary from (9 to 14) per cent on average.

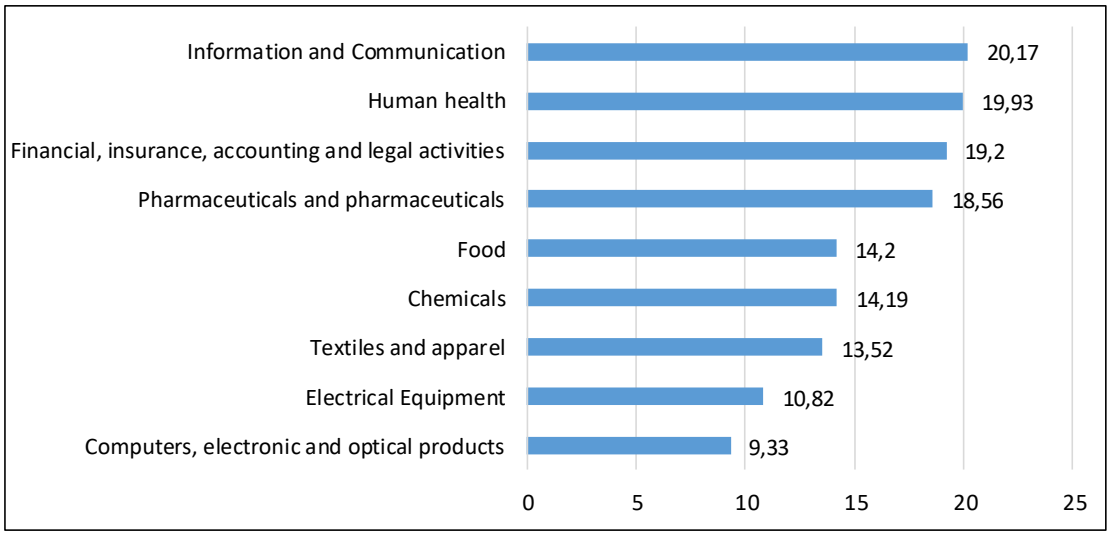

Figure 8. Expenditure on R&D as a per cent of volume of sales

Numerous theoretical and applied studies have stressed the positive correlation between innovation and the volume of exports. Innovation improves the quality of products or introduces new or significantly improved technologies and organisational and marketing policies. This positive relation results generally in an increase in productivity and competitiveness, which are the critical variables for penetrating new markets and generating new or significantly improved products. On the other hand, exports motivate companies to improve their innovation performance (Fonchamnyo & Wujung, 2016; Aghion, et.al. 2018). The survey results show, however, a modest ability of the sampled establishments to generate exports and compete in the global markets, since (59) per cent of these establishments direct about (87) per cent of their sales to the local market. The percentage of their exports to total sales is at most (13) per cent on average.

However, export performance varies within sectors, as shown in Figure (9). The percentage of exports to total sales ranges between (15) to (33) per cent on average, representing a reasonable percentage of shares. These sectors with reasonable performance include information and communication, pharmaceutical and pharmaceutical materials, computers, electronic and optical products, health care, and chemicals (Figure 9).

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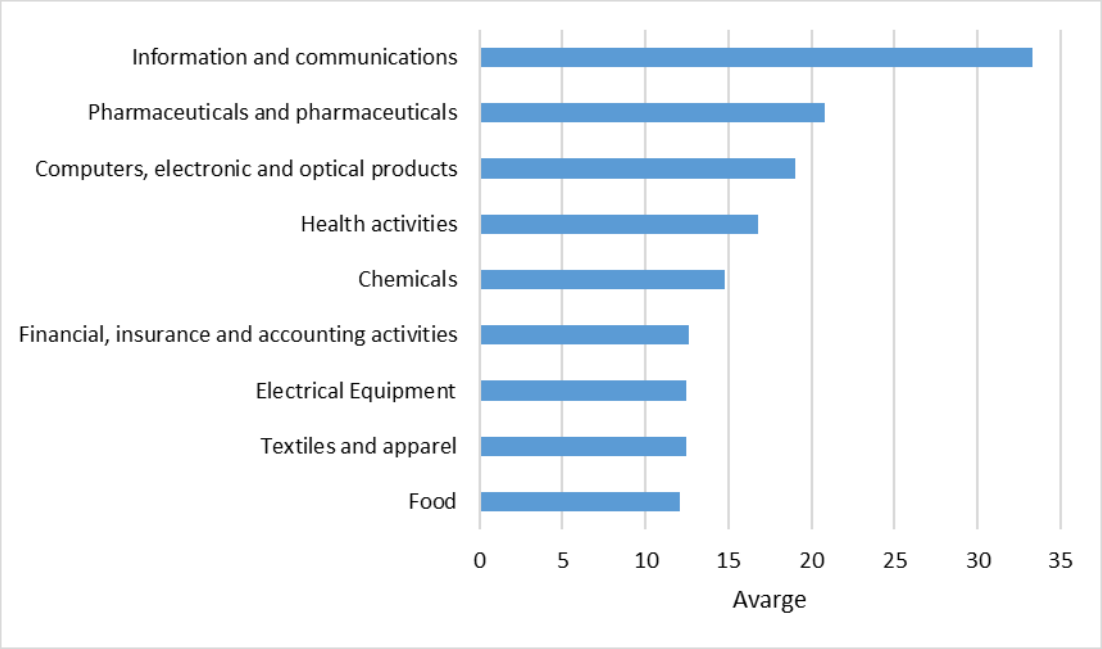

Figure 9. Average volume of Exports as a per cent of sales (%)

4.4. Dimension 4: RDI Cooperation with other institutions

Given the structural features of Egypt's R&D Human Resources based on official data of (2020), with more than (70) per cent of researchers working in universities, around (15) per cent occupied in government research centres, and a remaining limited number accounting for (6 -8) per cent researchers employed in the production sector and other civil society institutions, RDI in business enterprises would necessarily need both technical support and sometimes financing from other domestic and/or foreign institutions. Figures (10) and (11) summarise the survey results concerned with sources of finance and type of research cooperation.

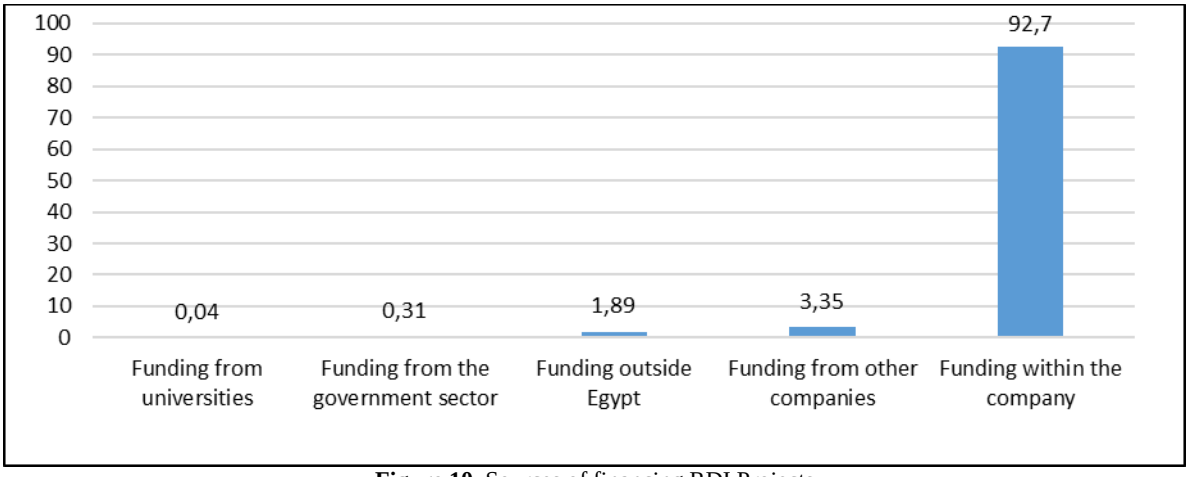

Figure 10. Sources of financing RDI Projects

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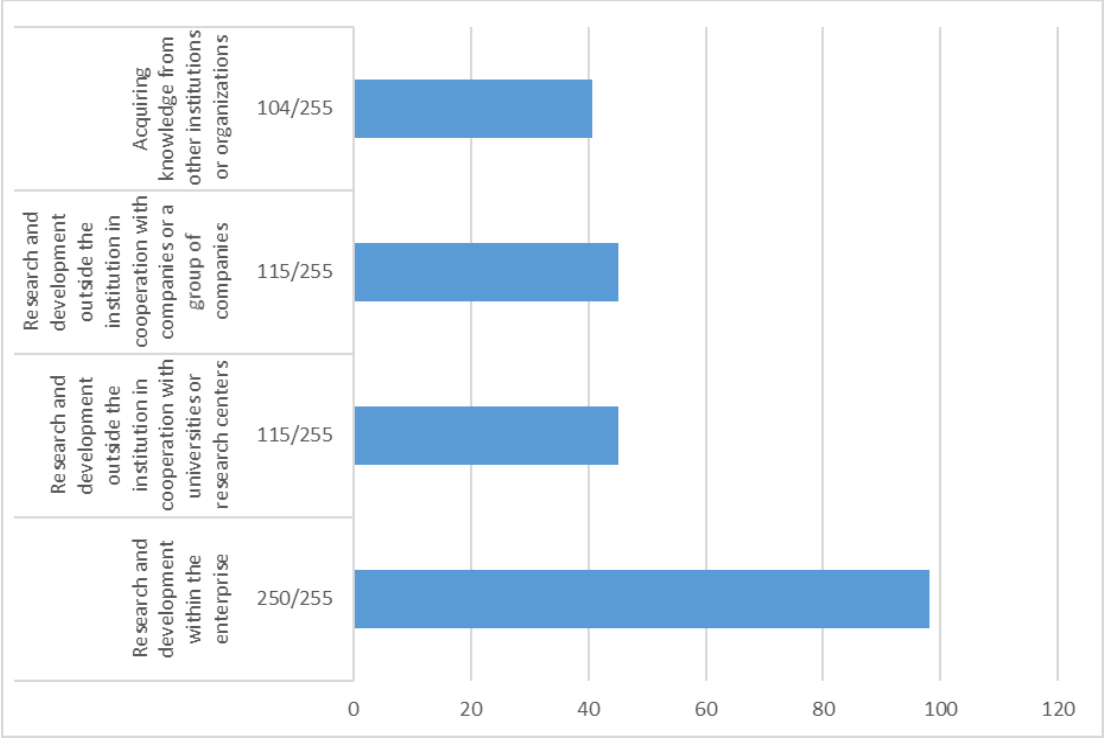

Figure 11. Research Cooperation with domestic institutions

Results from the survey (figure 10) reflect, however, a reversed point of view and different opinion: i) more than (90) per cent of the survey responses suggest that research and innovation financing is the primary responsibility of the business enterprise itself, ii) other sources of finance are negligible since they do not exceed (3.5) per cent of the sampled enterprises, iii) the contribution of the outside world in financing RDI activities in Egypt does not exceed (2) per cent at most. Research cooperation modes based on the results of the survey can be summarised as follows; i) most of the sampled companies (98 per cent) have their research activities with no external support or cooperation, ii) about (45) per cent of the surveyed business enterprises relies however upon carrying out their research and innovation projects either on universities or a cluster of other production companies, iii) in executing their research and innovation projects, (40) per cent of the business enterprises use some knowledge transfer channels such as the outcome of published papers, scientific conferences, joint research projects, intellectual property rights and facility sharing with universities and research centres. These results stress that Egyptian business enterprises need to enhance their cooperation with other RDI-producing institutions to benefit from comparative advantages and improve the quality of RDI outputs. In principle, working with research and innovation centres and universities accelerates the acquisition of new knowledge and increases the stock of knowledge of business enterprises. (Khorshid, 2020; Alam et al., 2019).

5. Summary and Conclusion

This paper suggested a two-stage methodology designed to assess the performance and impact of research, development and innovation (RDI) in business enterprises. The methodology begins with establishing a conceptual model or an integrated analytical framework that captures the increasing role of RDI system in the knowledge era of the twenty-one century, as well as its wide socioeconomic development impact on a country, and then with the development of a statistical survey that is particularly used to generate appropriate analytical and planning indicators for estimating the role and impact of RDI. Based on the above rationale, the conceptual modelling approaches to analyse RDI performance in business enterprises and evaluate its impact on knowledge

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transformation is concretised by four specific dimensions. These dimensions include i) Inputs for producing RDI, ii) Alternative RDI output categories, iii) RDI pertaining to a specific sector in the production sphere of the national economy, and iv) Modes of RDI cooperation between business enterprises and other national institutions (mainly RDI producing institutions such as universities and research centres), industrial clusters for innovation, and other social societies.

The performance indicators of the Egyptian economy's research, development and innovation (RDI) are collected and analysed at the enterprise level using a comprehensive statistical survey. The survey elements are selected from the governorates of Greater Cairo, following the International Standard Industrial Classification of economic activities (Revision 4), reflecting the contribution of economic activities to the gross domestic product of a country. The selected establishments comprise a representative sample of manufacturing and services enterprises with a minimum number of workers per establishment accounting for 25 persons.

The survey results revealed several analytical points and specific imbalances of RDI system in business enterprises that need to be addressed by policy makers. First, based on the full-time-equivalent (FTE) estimation approach, the number of RDI knowledge workers is relatively small, and its ratio to the total labour force is limited. The ratio of knowledge workers varies, however, from one economic sector to another, considering the used production techniques on the one hand and the adopted policy measures to enhance RDI activities on the other hand. A major structural imbalance in the RDI sector of Egypt, based on official indicators from ESTIO, 2019, is that around (60) per cent of research and development human capital is working in the higher education sector, (32) per cent of researchers are engaged in government research centres. Private Business enterprises and other non-government non-profit institutions are left with only (6 to 8) per cent of the aggregate research labour force. It is worth noting that the percentage share of researchers in the business sector of advanced industrial countries such as Japan, the USA, and Germany vary from (60 to 80) per cent of the aggregate researcher labour force, respectively. This imbalance applies as well to the output of RDI. Furthermore, the analytical results show that the employees of the production enterprises represented in the survey generally need more skills to produce innovation. This drawback requires adopting a comprehensive policy package for training, re-orientation and capacity building within a clearly defined life-long-learning (LLL) strategy.

Second, investment in intangible assets to produce innovative goods and services and significantly improve manufacturing, managerial and marketing operations is relatively limited, except for staff training. Spending of the sampled enterprises on R&D provided by research centres and universities is less than (6%), on average. Purchase or acquisition of intangible assets, such as informatics and database developments, research consultation, industrial designs, trademarks, and patents, accounts only for about (15) per cent of the gross RDI expenditure of the firm. Note here that intangible assets in most advanced RDI-producing countries account for (40-50) per cent of the total value of the productive assets. Most of the remaining spending on RDI is purchases of computers and other equipment (25%), compensations of research employees (17%), and consumption of intermediate goods (15%).

Third, with respect to RDI outputs, the highest output type is industrial designs which represent a component of the enterprise's intangible assets. The remaining RDI products generated by the sampled business enterprises, including new (or significantly improved) commodities or services, licensed property income, innovation of the production process, patents and commercial marks (which represent part of the enterprise’s innovation activities) account for a small percentage of their outputs. These results stress the need to enhance RDI outputs of business enterprises and diversify the scope of their outputs, towards more creative and innovative activities.

Fourth, despite the modest capacity of the sampled enterprises to innovate, export and produce intangible assets, investments in RDI show moderate positive economic return. The most important economic Impact of RDI is the considerable increase in the size of goods and services produced, which account for (39) per cent on average. The

penetration into new commodity markets represents the third RDI economic effect, with an increase of (21) per cent. The impact of reducing production and labour cost is less than the increase in sales volume.

Fifth, based on the results of the survey, financing needs represent the most important barrier to applying RDI in business enterprises (with a probability of (39) per cent), followed by the fact that managers might not necessarily be convinced of its relevance and benefits (with an associated probability of about (24) per cent). There is also a common feeling inside the enterprise that fluctuations and volatility of economic markets is a third barrier for carrying out RDI in business enterprises with (16.5) per cent relative probability. Another significant barrier to RDI is the need for qualified researchers or knowledge workers (with 6.1 per cent probability). The last and most important barrier is the increased percentage share of several business enterprises in the economy's informal sector, where RDI culture is practically absent.

Sixth, numerous theoretical and applied studies have highlighted the positive correlation between innovation and exports. Given the modest performance of the selected sample of Egyptian enterprises concerning innovation capacity, the results confirm their limited ability to generate exports and compete in the global markets. ((59) per cent of these establishments direct (87) per cent of their sales to the domestic markets).

Seventh, results from the survey suggest that more than (90) per cent of the sampled business enterprises rely mainly on self-financing of research and innovation. Other sources of finance are negligible since they are, at most (3.5) per cent of the number of sampled enterprises. Furthermore, the contribution of the outside world to finance RDI activities in Egypt is at most (2) per cent at most. On the other hand, most of the sampled business enterprises (98 per cent) have their research activities with no external support or cooperation. In addition to their self-financed own RDI projects, about (45) per cent of the surveyed business enterprises rely on carrying out their research and innovation projects either with universities or clusters of other production companies. Furthermore, in executing their research and innovation projects, (40) per cent of the business enterprises benefit from knowledge transfer channels such as published papers, scientific conferences, joint research projects, intellectual property rights, facility sharing with universities and capacity building. These results stress that Egyptian business enterprises need to enhance and diversify their cooperation with other RDI-producing institutions to benefit from comparative advantages and improve the quality of RDI outputs.

References

Aghion, P., Bergeaud, A., Lequien, M., & Melitz, M. J. 2018. The impact of exports on innovation: Theory and evidence (p. 678). New York, NY, USA: National Bureau of Economic Research.

Alam, A., Uddin, M., & Yazdifar, H. 2019. Institutional determinants of R&D investment: Evidence from emerging markets. *Technological Forecasting and Social Change*, 138, 34-44. https://doi.org/10.1016/j.techfore.2018.08.007

Beld, Bart. The effects of R&D investment on firm performance. BS thesis. University of Twente, 2014.

Cornell University, INSEAD, & WIPO. 2020. The Global Innovation Index 2020: Who Will Finance Innovation? Ithaca, Fontainebleau, and Geneva. https://www.wipo.int/edocs/pubdocs/en/wipo_pub_gii_2020.pdf

Chen, T. C., Guo, D. Q., Chen, H. M., & Wei, T. T. (2019). Effects of R&D intensity on firm performance in Taiwan's semiconductor industry. *Economic Research-Ekonomska Istraživanja*, 32(1), 2377-2392. https://doi.org/10.1080/1331677x.2019.1642776

ESTIO. 2019. Egyptian Academy of Scientific Research and Technology (2019). Science and Technology Indicators, 4, August.

Fernández-Sastre, J., & Montalvo-Quizhpi, F. (2019). The effect of developing countries' innovation policies on firms' decisions to invest in R&D. *Technological Forecasting and Social Change*, 143, 214-223. https://doi.org/10.1016/j.techfore.2019.02.006

Fonchamnyo, D.C., & Wujung, V.A. 2016. Innovation and Export Performance: An Empirical Insight on the Effect of Innovation on Manufacturing Firms in Cameroon. *Applied Economics and Finance*, 3(4), 123-133. http://dx.doi.org/10.11114/aef.v3i4.1682

Ismail M.O., Helmy, & Ramadan, M. 2020, Research, Development and Innovation in Business Enterprises of Egypt, Chapter (5), Executive Summary of Project "Development Return of Scientific Research and Innovation in Egypt", Academy of Scientific Research and Technology (ASRT), Egypt.

Jin, Z., Shang, Y., & Xu, J. (2018). The Impact of Government Subsidies on Private R&D and Firm Performance: Does Ownership Matter in China's Manufacturing Industry? *Sustainability*, 10(7), 2205. https://doi.org/10.3390/su10072205

Kemp, R.G., Folkeringa, M., De Jong, J.P., & Wubben, E.F. (2003). Innovation and firm performance (No. H 200207). Zoetermeer, The Netherlands: EIM.

Khorshid, M. 2015. Measuring Research, Development and Innovation Indicators in the Arab Countries – A Concept Paper. Arab Knowledge Report, UNDP, Beirut, Lebanon.

Khorshid, M. 2018. Development Return of scientific Research and Innovation – Approaches and Comparative Performance Measures, the Tenth Annual Report, the Arab Thoughts Foundation, Beirut, Lebanon.

Khorshid, M. 2022. Scientific Research and Innovation for deepening domestic industry in Egypt, paper No. (12), Deepening Domestic Industry in Egypt Project, Institute of National planning (INP), Cairo, Egypt.

Kim, H., Kim, Y., & Cho, K. (2014, July 3). The effect of research and development investment and desorptive capacity on firm performance. *Asian Journal of Technology Innovation*, *22*(2), 252-267. https://doi.org/10.1080/19761597.2014.973163

Leung, T., & Sharma, P. (2021, July). Differences in the impact of R&D intensity and R&D internationalization on firm performance – Mediating role of innovation performance. *Journal of Business Research*, 131, 81-91. https://doi.org/10.1016/j.jbusres.2021.03.060

Luo, X., Cao, D., Tjahjono, B., & Adegbile, A. (2022, February). Business model innovation themes of emerging market enterprises: Evidence in China. *Journal of Business Research*, 139, 1619-1630. https://doi.org/10.1016/j.jbusres.2021.10.080

Maietta, O. W. (2015, September). Determinants of university–firm R&D collaboration and its impact on innovation: A perspective from a low-tech industry. *Research Policy*, 44(7), 1341-1359. https://doi.org/10.1016/j.respol.2015.03.006

O'Connell, V., AbuGhazaleh, N., Tahat, Y., & Whelan, G. (2022, July 25). The Impact of R&D Innovation Success on the Relationship between R&D Investment and Financial Leverage. *Journal of Open Innovation: Technology, Market, and Complexity*, 8(3), 129. https://doi.org/10.3390/joitmc8030129

OECD, 2018, Science, Technology, and Industry Outlook 2008. OECD publishing, Paris, France
https://doi.org/10.1787/sti_outlook-2008-en

OECD. 2015. Frascati Manual, 2015: Guidelines for Collecting and Reporting Data on Researchand Experimental Development, The Measurement of Scientific, Technological and Innovation Activities, OECD Publishing, Paris. http://dx.doi.org/10.1787/9789264239012-en

OECD/Eurostat. 2018. Oslo Manual, 2018: Guidelines for Collecting, Reporting and Using Data on Innovation, 4th Edition, The Measurement of Scientific, Technological and Innovation Activities, OECD Publishing, Paris/Eurostat, Luxembourg.
https://doi.org/10.1787/9789264304604-en

OECD. 2019. University Industry collaboration: new evidence and policy options, OECD publishing, Paris, France.
https://doi.org/10.1787/e9c1e648-en

Öztürk, E., & Zeren, F. (2015). The Impact of R&D expenditure on firm performance in manufacturing industry: further evidence from Turkey. *International Journal of Economics and Research*, 6(2), 32-36.

Pradeep, V., Bhattacharya, M., & Chen, J.R. 2017. Spillover Effects of Research and Development, Exports and Foreign Investment on Productivity: Empirical Evidence from Indian Manufacturing. *Journal of South Asian Development*, 12(1), 18-41.
https://doi.org/10.1177/0973174117700467

Taques, F.H., López, M.G., Basso, L.F., & Areal, N. 2021. Indicators used to measure service innovation and manufacturing innovation. *Journal of Innovation & Knowledge*, 6, 11-26. https://doi.org/10.1016/j.jik.2019.12.001

Rezk, M. R. A., Ibrahim, H. H., Radwan, A., Sakr, M. M., Tvaronavičienė, M., & Piccinetti, L. (2016). Innovation magnitude of manufacturing industry in Egypt with particular focus on SMEs. *Entrepreneurship and Sustainability Issues*, 3(4), 307-318. https://doi.org/10.9770/jesi.2016.3.4(1)

United Nations Conference on Trade and Development (UNCTAD) (2019). General Profile: Egypt, 16 April. Available at https://unctad.org/system/files/official-document/tdr2019_en.pdf

UNDESA. 2008. International Standard Industrial Classification of All Economic Activity, United Nations Department of Economic and Social Affairs, Statistical Division, Statistical Papers, Series M, No.4, New Yorkhttps://unstats.un.org/unsd/publication/seriesm/seriesm_4rev4e.pdf

UNDP/MBRF. 2021. Research, Development and Innovation in "Global Knowledge Index", UNDP Regional Bureau of Arab States, and M. Bin. Rashid Association for Knowledge, 39-45.

UNESCO. 2010, Measuring R&D: Challenges Faced by Developing Countries, Technical Paper no. 5, UNESCO, Paris, France.

UNESCO Institute for Statistics. 2014. Guide to Conducting an R&D Survey Montréal, Quebec, Canada.

WIPO. 2021. Global Innovation Index 2021: Tracking Innovation through the COVID-19 Crisis. Geneva: World Intellectual Property Organization available at https://www.wipo.int/edocs/pubdocs/en/wipo_pub_gii_2021.pdf

World Bank, 2022. World Development Indicators | Data. [online] Available at: https://data.worldbank.org/data-catalog/world-development-indicators, Accessed 20 August 2022.

World Intellectual Property Organization (WIPO) (2021). IP Facts and Figures 2021. Geneva: WIPO.

World Trade Organization (2019). Trade Profiles https://www.wto.org/english/res_e/booksp_e/trade_profiles19_e.pdf

Yigitcanlar, T., Sabatini-Marques, J., Kamruzzaman, M., Camargo, F., Moreira da-Costa, E., Ioppolo, G., & Palandi, F. E. D. (2018, May 1). Impact of funding sources on innovation: evidence from Brazilian software companies. *R&D Management*, 48(4), 460-484. https://doi.org/10.1111/radm.12323

Zangara, G., Cosma, A., & Filice, L. (2023). Impact analysis of Industry 4.0 in SMEs: Harmonic innovation as a virtuous evolution for the community development. *Procedia Computer Science*, 217, 1370-1377. https://doi.org/10.1016/j.procs.2022.12.335

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