RESEARCH AND DEVELOPMENT AS POTENTIAL DRIVER OF EGYPT'S PHARMACEUTICAL INDUSTRY

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INTRODUCTION

The present study explores the relation of expenditure on R&D to output at the firm level, taking the pharmaceutical industry as a case for study. It addresses the following research question: what is the nature and extent of the effect of R&D on pharmaceutical output? It is thus motivated by interest in *measuring* the elasticity of output with respect to R&D, and by curiosity about the role of R&D in driving the growth of the pharmaceutical industry in Egypt.

To explore the relation of R&D to output, we begin with a definition of R&D. It is the planned and creative work aimed at discovering new knowledge and developing new or significantly improved goods and services.[1] R&D is of three distinct types, namely: *basic research*, *applied research* and *development*. *Basic research* includes activities purely aimed at acquiring new knowledge *without* having an immediate commercial application or use in mind (e.g., finding new molecule(s)). *Applied research* includes activities which may build on the results of basic research with the aim of solving practical problem(s) or reaching specific commercial applications/goals. *Development* involves the use of knowledge (facts and principles) gained from research (basic and applied) in order to produce useful materials, systems, methods and products. It therefore includes the design and development of prototypes, as well as the production of significantly improved goods, services or processes (U.S. Census Bureau and the National Science Foundation 2010:3).

The above definition links R&D to the creation of knowledge (especially of the technical type) which, in turn, fuels innovation. A 'stepped-up' rate of innovation drives faster growth in output and in productivity (both being requisites of sustainable economic growth) (Porter and Stern 2004:1). The relation of R&D to output and productivity holds at both the macro- and micro- levels. Herein lay our interest in measuring firm-level elasticity of output with respect to R&D.

As for curiosity about the role of R&D in driving pharmaceutical industry growth in Egypt, we note that although the industry's contribution to manufacturing value added, exports or employment has, to date, been quite modest (see details below), it still has growth potentials especially in today's knowledge-based economy. International experience associates firm-level R&D expenditure with the industry's growth. Between 1995 and 2004, a 33 percent growth in the R&D expenditure of Indian pharmaceutical firms was associated with a 16 percent growth in industry sales. Respective growth rates for 2005-2007 were 24

[1] Meanwhile precluding routine product testing, quality control or technical services unless they are an integral part of an R&D project.

and 13 percent (calculated from Figure (1) in Chandan 2011:7). For perspective, India holds a 1-2 percent share of the global pharmaceutical market of generic drugs and active ingredients. Among India's top pharmaceutical firms, Dr. Reddy's Laboratories Ltd. confirmed that the firm realized that R&D was the key to its growth, especially post-2005 when most firms oriented their expenditure to developing new drugs.[2]

Evidently, firm-level R&D expenditure may drive industry growth. Therefore, Egypt's firms may be well advised to raise their modest expenditure (as will be shown later). However, this comes against a backdrop of the recent heated debate over the June 2012 Ministry of Health's decision to liberalize the price of newly-registered drugs.[3] The consequent rise in prices will not only have implications for large segments of the population consuming these drugs, but it may also pose a challenge to firms wishing to raise their R&D expenditure. Increased expenditure constitutes an additional cost which may find its way to further price hikes. However, if R&D were to translate into output and productivity gains, such cost effects may be mitigated, hence furthering our interest in exploring the relation of R&D to output at the firm level.

Our methodology for exploring the effect of R&D on output rests on estimating a knowledge production function using a panel of 29 pharmaceutical firms employing more than 50 persons (over the period 2004-2009). Obtaining estimation results, we draw some macro- and micro-related explanations for the weakness of Egypt's economy-wide R&D performance, and that of pharmaceutical firms. To do so we *first* provide an overview of macro-level R&D, and *second* conduct 5 in-depth interviews of selected pharmaceutical firms in Egypt. Interviews aim to shed light on pharmaceutical R&D performance at firm level.

The present paper thus aims to fill a gap in the literature with relevance to the pharmaceutical industry in Egypt, especially in providing an applied work. Indeed applied works with relevance to the industry have remained quite sparse. To date, the bulk of the industry-related works has been either descriptive or has focused almost exclusively on the

[2] For perspective, the firm's R&D intensity (expenditure relative to sales) surged from 7.2 percent (average 2000-2004) to 11.5 percent (2005-2008) (calculated from Table (1) Chandan 2011:7). We note that in 2005 the trade related intellectual property rights agreement (TRIPS) came into effect. This was associated with drug patent protection, hence the increased interest in spending on the development of new drug(s).

[3] The ministry announced that drug prices were to be determined on the basis of comparable international prices. In response to serious opposition, the ministry temporarily decided to take the lower of the two prices determined either on the basis of comparable international price with a 40 percent additional reduction, or on the basis of the cost-plus method. Either way, if such a decision were to be finalized, it would bear directly on the price of drugs consumed by large segments of the population.

implications of the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) for the industry.

After the introduction, the paper is organized as follows: Section I reviews the relevant literature; Section II gives a general profile of the pharmaceutical industry in Egypt (structure and contribution to manufacturing output and exports); Section III reports the knowledge production function estimation results; Section IV attempts to explain R&D performance as revealed through estimation results, *first* via macro-level R&D outlook, and *second* via micro-level in-depth interviews; Section V concludes with relevant macro- and micro-level policy implications.

I. REVIEW OF LITERATURE

R&D literature is quite voluminous. It can be broadly classified as literature that: links R&D to output and productivity or to the growth thereof; examines the determinants of R&D; explores the relation of R&D to innovation; estimates returns to R&D. We stop only at signposts with relevance to the relation of R&D to output and its link to innovation,[4] subsequently reviewing literature with relevance to Egypt's case.

A seminal contribution towards exploring the relation of R&D to output and productivity is Griliches (1979). Using a 'knowledge production function approach', the author incorporates a variable measuring "the current state of technical knowledge (determined in part by current and past R&D expenditures)" in a standard Cobb-Douglas production function.[5] The author follows the tradition of exploring the relation of R&D to output through econometric estimates, but also refers to the use of historical case studies as common practice. In the same vein, Mairesse and Sassenou (1991) indicate that R&D parameter estimates obtained from econometric methods should be:

> Seen as abstract constructs designed to summarize and quantify approximately major phenomena, or certain important aspects of them.
>
> Econometric methods…need to be supplemented and cross fertilized by individual case studies. Well-designed and rigorously executed case studies can provide detailed descriptions and in-depth knowledge of complex phenomena (Mairesse and Sassenou 1991: 26-28).

[4] For a comprehensive overview of seminal works on R&D, see Mairesse and Sassenou 1991. For works on the determinants of R&D intensity (expenditure on R&D relative to sales) see Grabowski (1996); returns on R&D, see Levin et al. (1987) and Hall (1996).

[5] Using data for industrial firms from U.S. National Science Foundation R&D annual survey, together with the statistics of the Census of Manufacturing.

Further to these views, surveys may contribute substantially to an explanation of inter-industry differences in R&D intensity and innovative performance (Levin et al. 1987:815). Interviews (and similar qualitative approaches) may also be carried out in an open-ended manner, thus revealing new and unanticipated information that plays a role in explaining the issue of study (Rodrik 2008:16). It is against this backdrop that we employ both an econometric estimation together with a set of in-depth interviews of selected pharmaceutical firms in Egypt.

Later works of Griliches distinguish between basic and applied research.[6] Griliches (1986) finds firms allocating a bigger share of their total R&D expenditure to basic research to be more productive than those favouring applied research (Griliches 1986:147). These findings are in tune with Mansfield (1980) who also finds basic research to be more productivity-enhancing, compared to applied research.[7]

On another note, Griliches and Lichtenberg (1984) distinguish between product- and process-related R&D performed by the firm/industry itself, and that which is 'embodied' in intermediate goods produced by other firms/industries. The authors find process R&D performed by the industry itself to have a bigger contribution to growth in total factor productivity than product R&D whether performed by the industry itself or embodied in intermediate products (Griliches and Lichtenberg 1984:328).

Variations of the early contributions of Griliches have greatly enhanced the R&D-output and productivity estimations. For example, Scherer (1982) developed a model regressing labour productivity on the stock of R&D capital, and on capital and intermediates (both measured per unit of labour), meanwhile introducing R&D with a lag. Subsequently, Mairesse and Hall (1996) developed more elaborate estimations in which they highlighted the need to purge labour and value of capital of the share of the two factors engaged in R&D to avoid double counting, and on the use of the generalized method of moments to correct for simultaneity of output (or sales) and both capital and R&D expenditure[8] in their estimation.

In reference to innovation, Evangelista et al. (1997) indicate that innovation generally comes under the umbrella of technological change, which stems either from formal knowledge (written and codified in books, manuals, patents and designs), or from the

[6] Using multiple data sets of manufacturing firms employing more than 1000 persons (ranging from the smallest data set of 386 firms to the largest of 652).

[7] With application to 20 U.S. industries over the period 1948-66, and 16 firms over the 1960-76 period.

[8] As instruments they use three-year lags of capital and R&D.

informal one (tacit and uncodified). The authors thus differentiate between technological change which consists of *tangible* and easily-identifiable activities such as the introduction of new machinery and equipment, and that which is *intangible* as evident in the generation of new ideas, inventions and innovations. They further indicate that R&D expenditure was traditionally considered to be the main source of innovation. However, contemporary focus has shifted to complementary sources which are external to the firm (including: the design of capital goods (Archibugi, Cesaratto and Sirilli 1191:300) which may be continuously modified to keep up with user needs, and the technological environment, i.e., the so-called external knowledge base (van Leeuwen and Klomp 2002:9)).

Based on survey data, Freel (2000) investigates the relationship between innovation and 'firm growth and performance'[9] (measured by: sales growth; employment growth; growth in profits and absolute profit levels; sales turnover per full time employee as a measure of productivity; export intensity or export propensity measured as a binary variable). Findings indicate that innovating firms tend to have higher rates of growth both in sales and employment compared to non-innovating ones. However, evidence on innovating firms having higher profits or greater export intensity is less conclusive.

R&D literature with relevance to Egypt tends to be centered around intellectual property protection (see, for example, Shallabi 2010; Balat and Loutfi 2007; Qenawy 2001; Subramanian and Abdel-Latif 1997). Otherwise, it tends to be descriptive of the pharmaceutical industry (see, for example, Handoussa and El-Shenawy 2004; Arif 2010).

With regard to intellectual property, Shalabi (2010) comprehensively outlines the key implications of the TRIPS for Egypt's pharmaceutical industry (and its counterparts in many other developing countries). Among these implications is that TRIPS gives developing countries that hold a compulsory license to produce an active ingredient (raw material) of a particular drug the permission to export it to another country without the consent of the patent holder (referred to as 'parallel' imports).[10] As such, many developing countries were empowered with the ability to import raw materials at affordable costs from third countries (producing them under compulsory licensing) so as to feed their domestic pharmaceutical

[9] Other studies have explored this relation albeit in a knowledge production function framework, see e.g., Lööf and Heshmati (2002).

[10] However, TRIPS forbade parallel imports of generic versions of brand name drugs produced under compulsory license—the implications being that the producing country can only supply the domestic market.

production (mostly generics).[11] TRIPS also gave developing and least developed countries the right to infringe patents on pharmaceutical products if the product was proved to be of dire need to public health (known as the necessity test). The agreement also considered all drugs registered before 1995[12] to be in the public domain. They can, thereby, be produced without the consent of the patent holder. Otherwise, all product and process innovations are to be patented for a period of 20 years. However, the respective period is often criticized for being too long, perhaps extending well beyond the life cycle of the product.

In reference to R&D, Shallabi (2010) further indicates that large global corporations (especially the ones undergoing restructuring) have been increasingly contracting out their R&D activity. Shallabi further highlights that R&D is often the driver of many strategic alliances and mergers and acquisitions. In the first case, globally dispersed pharmaceutical firms may engage in cooperation agreements for the sole purpose of R&D.[13] In the second, mergers may be driven by interest in overtaking prominent research projects, thus acquiring intellectual property rights upon their completion and registration.

II. PROFILE OF THE PHARMACEUTICAL INDUSTRY IN EGYPT

In this section we sketch a profile of the pharmaceutical industry in Egypt over the period 2001-2010 (at three points in time). We explore the industry's contribution to output, value added, employment and exports of the manufacturing industry at large. We further look at the relative importance of different-sized private and public sector firms to the pharmaceutical industry with relevance to all four variables. Finally, we highlight the structure of the industry by firm size (as per number of employees), and the pattern of geographic concentration across the governorates of Egypt.

As evident from Figure 1, the pharmaceutical industry has assumed, on average, a 4 to 5 percent share of total manufacturing output, a slightly higher 5 to 6 percent share of its value added. Its contribution to employment has been around the 3.5 to 4 percent mark, and manufactured exports around 2 to 3 percent. Although not a major contributor to manufacturing, it remains an industry of relatively high female intensity as will be discussed

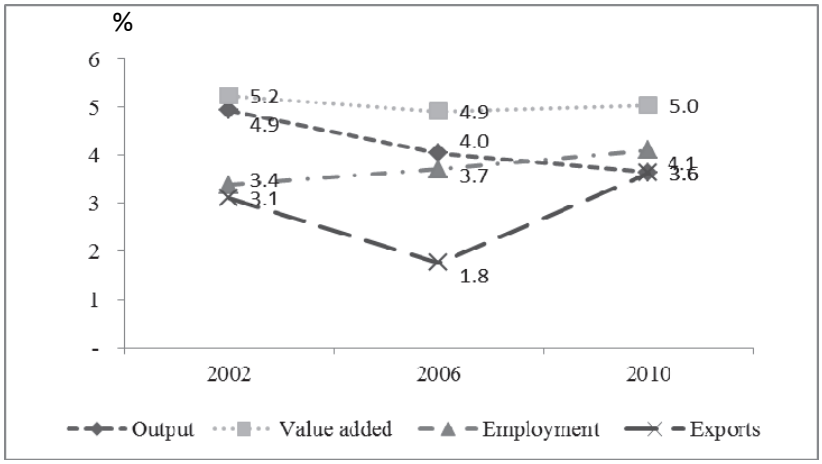
[11] However, the agreement forbade the producers of the respective ingredients from exporting them to developed countries so as not to hamper the R&D associated with finding and developing new active ingredients or similar raw materials (Shalabi 2010:265).

[12] The date of TRIPS initiation.

[13] For example, in 1995, Glaxo and Wellcome merged to form Glaxo-Wellcome, which in turn acquired California-based Affymax Research Institute with the objective of gaining access to the latter's biotechnology research.

later. Thus, the growth of the industry may have important social implications. Moreover, the industry acquires increased importance in today's knowledge-based economy.

Figure 1. Pharmaceutical Industry Contribution to Manufacturing Output, Value added, Employment and Exports (2002, 2006 and 2010)



Source: Author's calculations based on CAPMAS Annual Industrial Survey, different issues.

As for the structure of the pharmaceutical industry, we note that output, value added, exports and employment are overwhelmingly generated by large firms employing more than 100 persons, as shown in Table 1. All the more, the industry leans heavily towards large firms employing more than 500 persons.

Table 1. Contribution of Firms Employing More Than 100 Persons to Output, Value Added, Employment and Exports of the Pharmaceutical Industry (%) (2002, 2006 and 2010)

	2002	2006	2010
Share of firms with 100+ employees in **Output**	90	91	98
- Of which: firms with 500+ employees	65	68	79
Share of firms with 100+ employees in **Value Added**	92	92	99
- Of which: firms with 500+ employees	67	72	78
Share of firms with 100+ employees in **Employment**	93	91	99
- Of which: firms with 500+ employees	76	74	87
Share of firms with 100+ employees in **Exports**	86	90	90
- Of which: firms with 500+ employees	60	37	82

Source: Author's calculations based on CAPMAS Annual Industrial Survey, different issues.
Notes: - Data for public sector firms are for FY 2001/02, 2005/06 and 2009/10, while data for private sector are for the calendar years 2002, 2006 and 2010.
- For the years 2002 and 2006, the above percentages are for the chemicals industry at large, while 2006 reflects those of the pharmaceutical industry specifically. This is due to CAPMAS Annual Industrial Survey's adoption of ISIC Revision 3.1 in the earlier issues, while adopting Revision 4 in the latter. Rev.3.1 includes pharmaceuticals together with "code 24: manufacture of chemicals and chemical products," while under Rev.4 they are separately entered under "code 21: manufacture of basic pharmaceutical products and pharmaceutical preparations."

For the year 2010,[14] the distribution of firms by size across public and private sectors, their respective total employment and intensity of female employment, as well as value added are shown in Table 2.

[14] We have highlighted only the year 2010 because of CAPMAS' adoption of different ISIC classifications (as highlighted in the notes to Table 1).

Table 2. Pharmaceutical Industry Structure by Firm Size, Number of Employees and Value Added (LE 000s), 2010

	Public			Private			Total		
Firm size (by number of employees)	Number of firms	Employees (including the number of females and % of employees in the respective category)	Value added	Number of firms	Employees (including the number of females and % of employees in the respective category)	Value added	Number of firms	Employees (including the number of females and % of employees in the respective category)	Value added
Less than 10				1	8 (0)	182	1	8 (0)	182
11-24				6	90 (23; 26%)	3,657	6	90 (23; 26%)	3,657
25-49				4	148 (35; 24%)	8,325	4	148 (35; 24%)	8,325
50-99				4	317 (38; 12%)	28,182	4	317 (38; 12%)	28,182
100-499				20	4,825 (1,316; 27%)	1,219,903	20	4,825 (1316; 27%)	1,219,903
500+	8	17,227 (6,559; 38%)	986,938	14	19,699 (5,515; 28%)	3,443,717	22	36,926 (12,087; 33%)	4,430,655
Total	8	17,227	986,938	49	25,087	4,703,966	57	42,314	5,690,904

Source: CAPMAS Annual Industrial Survey, 2009/10 and 2010.

In total, there are 57 pharmaceutical firms in Egypt, of which 8 are public sector firms. The latter fall exclusively in the category of 500+ employee firms, and exhibit a high intensity of female employment (38 percent). They account for 41 percent of total pharmaceutical industry employment, and 17 percent of its value added. In the same category come 14 private sector firms which exhibit a 28 percent intensity of female employment, and contribute 49 and 61 percent of the industry's employment and value added, respectively (calculated from CAPMAS Annual Industrial Survey, 2009/2010 and 2010). Moreover, public and private sector firms are geographically concentrated around Greater Cairo, parts of the Delta, Giza and Alexandria, in the respective order.

Worldwide, the size of the pharmaceutical market is estimated to be US$875 Bn—with Pfizer, Novartis, Merck and Co., Sanofi-Aventis, AstraZeneca and GlaxoSmithKline (GSK) occupying top six positions (with shares of global sales ranging from 7 to 4 percent) (IMS 2011:3). Many of these global corporations have subsidiaries operating in Egypt, albeit with a slightly different ranking, whereby GSK comes first with an approximate market share of 7.5 percent. GSK is followed by: Novartis (6.7 percent); Sanofi Aventis (6.3 percent); Pfizer (4.2 percent); Bristol-Myers Squibb (BMS)[15] (4.2 percent) (AMCHAM 2006).

III. Model Estimation and Sensitivity Analysis

Using panel data for 29 pharmaceutical firms in Egypt employing more than 50 persons over the period 2004-2009, we estimate a Cobb-Douglas functional form of the "knowledge production function" (reviewed above). We follow the tradition of Griliches (1979, 1986), Mansfield (1980), Mairesse and Sassanou (1991), and many variations of the same model.[16] We subsequently employ sensitivity analysis to investigate the effect of two hypothetical R&D expenditure scenarios on output.

We model Egypt's pharmaceutical firms' R&D expenditure in relation to output as follows:

$$Y_{it} = A\, L_{it}^{\beta l}\, K_{it}^{\beta k}\, R_{it}^{\beta r}\, e^{u_{it}} \qquad (1)$$

$$i = 1, \ldots, 29 \; ; \; t = 1,..,6$$

where, A= technology/technological change parameter (i.e., total factor productivity);

Y_{it} = value of real output of firm i at point t in time;

[15] Although BMS does not appear on the list of top six global corporations.

[16] To name but a few of recent applied works: Rogers (2010), Wang and Tsai (2003); Lööf and Heshmati (2002); Wakelin (2000); Ug Kwon and Inui (2003).

L_{it} = total number of employees in firm *i* at point *t* in time;

K_{it} = value of real capital stock of firm *i* at point *t* in time;

R_{it} = value of real R&D expenditure of firm *i* at point *t* in time.

Taking the natural logarithm of both sides, we derive the following empirical specification:

$$\log (Y_{it}) = \log (A) + \beta_l \log (L_{it}) + \beta_k \log (K_{it}) + \beta_r \log (R_{it}) + u_{it} \qquad (2)$$

Output, capital and R&D expenditure are all deflated using the consumer price index (CPI) for health care issued by Egypt's "Central Agency for Public Mobilization and Statistics" (CAPMAS).[17] Output is measured as the value of output at sales price deflated, labour as total units of labour employed by the firm, capital as the value of the stock of fixed assets at year end.

Some caveats in estimation are worth noting: 1) in some empirical variations of model (1), R&D is reflected as R&D capital stock[18] and is constructed from the past history of R&D investment, with a per-annum rate of depreciation and a pre-sample annual rate of growth of R&D expenditure[19] (Mairesse and Hall 1996:5). However, for lack of past history of R&D investment by firm in the annual industrial survey, we could only use the value of R&D expenditure which appears as one entry in the firm's "other service requirements."[20] 2) To avoid double counting, other empirical variations purge the labour component of personnel working on R&D (researchers, scientists and laboratory technicians), while purging capital of the value of physical assets earmarked for R&D. However, given that CAPMAS annual industrial survey only allows for a breakdown of employees by managers, administrative staff, clerks, specialists, technicians, inspectors, operation workers and technical service workers,[21] we could only try one variation of the model with the labour component purged of

[17] The respective index is calculated with relevance to three main health care categories: pharmaceutical products (this category carries around 80 percent weight in the index), pharmaceutical equipment and other pharma products (such as cotton products of pharma use).

[18] Ortega-Argiles, Piva and Vivarelli (2011) indicate that dealing with R&D stocks, rather than flows, has two traditional advantages: on the one hand, since stocks incorporate the accumulated R&D investments in the past, the risks of endogeneity are minimized; on the other hand, there is no need to deal with complex (and often arbitrary) choice of the appropriate lag structure of the R&D regressor (Ortega-Argiles, Piva and Vivarelli 2011:14). We have included the latter in one of tested equations for lack of R&D stock data.

[19] Via the perpetual inventory method.

[20] Other entries include expenditure on: services rendered by others; maintenance; advertising; transport; leasing of equipment and transportation facilities; communication-related services such as internet; accounting services; subscriptions in various local and international agencies; insurance; taxes; bank charges.

[21] Where operation workers engage in various activities closely associated with production, while technical service workers engage in maintenance activities.

"specialists" and "technicians." As for capital, CAPMAS provides no breakdown of usage by R&D or otherwise, therefore not permitting purging.

The parameter estimate of α is estimated TFP, β_l, β_k and β_r measure the elasticity of output with respect to each of the regressors, and u_{it} is the error term assumed to behave normally. "α" may reflect either fixed or random effects. While fixed effects take into account (control for) unobservable characteristics particular to individual firms, random effects, in turn, account for individual random effects. In both cases, effects stand to vary with respect to the firm only (with α bearing the subscript *i*), with respect to time only (α bearing the subscript *t*), or with respect to both firm and time (with α bearing subscripts *i* and *t*). Performing Hausman's specification test, we concluded that the appropriate specification is to model α as fixed effects varying with respect to both *i* and *t*. The estimated model is thus rendered:

$$\log (Y_{it}) = \log (A_{it}) + \beta_l \log (L_{it}) + \beta_k \log (K_{it}) + \beta_r \log (R_{it}) + u_{it} \qquad (3)$$

Data for pharmaceutical firms were queried from CAPMAS electronic database of the annual industrial survey.[22] Because each firm included in the survey is not given the same reference number year after year, CAPMAS gave a distinctive code to each firm to allow for yearly tracking. We used a balanced panel[23] of 29 firms employing 50 or more persons[24] over the 2004-2009 period. Table 3 gives estimation results.

[22] Because each firm included in the survey is not given the same reference number year after year, CAPMAS gave a distinctive code to each firm in order to track firm data year after year.

[23] In the preparation of the dataset, we probed the option of using an unbalanced panel. However, one problem was that the dataset as coded by CAPMAS yielded 'consistently' missing data for the years 2001, 2002 and 2003. This was primarily due to missing identifiers in the original CAPMAS electronic database that further hindered their own coding process. Such consistency in missing observations results in the problem of "missing data" which, in turn, may yield biased and inconsistent parameter estimates.

[24] As medium enterprises, 50+ employee firms are those more likely to undertake any substantive R&D expenditure.

Table 3. Knowledge Production Function Estimation Results

Dependent variable / Independent variables	Log real output					Log real sales	Real output growth
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Intercept term (α)	5.872*** (0.991)	7.272*** (0.587)	8.175*** (1.094)	7.423*** (0.283)	8.349*** (0.835)	5.845*** (0.975)	0.037*** (0.009)
Log labour	0.314* (0.168)	0.073 (0.113)	0.045 (0.082)			0.301* (0.171)	
Log non-specialized labour				0.041 (0.069)	0.012 (0.049)		
Log real capital	0.340*** (0.066)	0.362*** (0.049)	0.301*** (0.074)	0.368*** (0.048)	0.305*** (0.078)	0.351*** (0.070)	
Log real R&D expenditure	0.030 (0.028)					0.029 (0.028)	
Log real R&D expenditure (-1)		0.030** (0.013)		0.031** (0.014)			
Log real R&D expenditure (-2)			0.032** (0.014)		0.032** (0.015)		
Labour growth							0.586** (0.235)
Real capital growth							0.389*** 0.0257
Real R&D expenditure growth							-0.005 (0.012)
R-squared	0.946	0.953	0.967	0.953	0.967	0.946	0.670
S.E. of regression	0.363	0.353	0.308	0.353	0.308	0.361	0.350
F-value	46.502***	43.439**	45.926***	43.408**	45.895**	46.497***	3.917***

Source: Author's estimation.

Notes: ***, ** and * indicate the estimated parameter is statistically significant at the 1%, 5% and 10% levels respectively; heteroscedastic-consistent standard errors of estimates in parentheses.

We present equations (1) and (6) as base cases which include real R&D expenditure together with labour and real capital. In both equations, labour and capital are statistically significant and the estimated parameters reflect a positive elasticity of output with respect to both factors. However, R&D is found to be statistically insignificant.[25] The literature forwards a number of possible explanations for such statistical insignificance (or weakness of the estimated parameters).

Explanations may pertain to macro-level, micro-level, or both (as indicated between parentheses): low R&D expenditure (*macro* and *micro*); low capacity to translate R&D expenditure into productivity gains owing to inadequate organizational structures and/or low R&D personnel intensity and an insufficient level of skills among employees (*macro* and *micro)* (Ortega-Argiles, Piva and Vivarelli 2011:9); unsuitable structures of corporate governance (*macro)*; weak university-business links (*macro and micro*); lack of fiscal incentives for the promotion of R&D investment (*macro*); poor utilization of the system of intellectual property rights (*macro*) (Rogers 2010:335). The relevance of the above explanations to Egypt's case is further discussed in Section IV.

Although labour does not establish statistical significance in equations (2) and (3), both capital and lagged R&D (at both 1 and 2-year lags) are found to be statistically significant. The latter result indicates that there may be some gestation period after which R&D expenditure may yield positive effects (i.e., adds to technical knowledge). Such a period may arise from a particular R&D project itself taking more than a year to complete. If successful, it may take more time before a decision is made to use or produce it. The lag may also be associated with the nature of innovation undertaken. If innovation were of the 'product' type, the lag may result from the time it takes for the innovation to be recognized and completely accepted in the market (commercialized). If of the 'process' type, the lag may result from the gradual introduction of the process itself (Griliches 1979:101, Griliches 1986:145 and CBO 2005:12). Based on the Akaike information criterion reported in equations (2) and (3), we conclude that the 2-year lag is the appropriate one.[26] We note, however, that other empirical

[25] Studies that estimate the private return to R&D by using data at the firm or industry-level… seem to form the basis for the consensus that the elasticity of R&D is positive and significant with a central tendency between 0.10 and 0.20. Among such studies, those that employ time series data show weaker results, with smaller coefficients and less statistical significance than those that use cross-sectional data. Fewer studies … using economy-wide data suggest a weaker effect of R&D on productivity. Results are also less uniform, … estimates of R&D elasticity span a wide range (from zero to 0.60) and are often insignificant (CBO 2005:14).

[26] Associated with a lower value Akaike Information Criterion (0.77 for the 2yr versus 1.01 for 1-yr lag).

studies have indicated that it may be advisable to use longer time lags.[27] This was, however, hindered by a relatively brief time frame of our data set.

As discussed earlier with relevance to purging labour and capital of the R&D-related elements, in equations (4) and (5) we purge the labour component of "specialists" and "technicians," but still find labour to be statistically insignificant. As noted earlier, capital could not be purged.

Using the parameter estimates obtained from equations (2) and (3) (where R&D is reflected with a lag of 1- and 2-years, respectively), we further employed sensitivity analysis to explore how output would grow relative to the fitted value of output (based on the estimated equation) in each year under two scenarios of a hypothetical *doubling* and *tripling* of firm-level R&D expenditure. To calculate the "what if" value of output, we assumed the number of labour units and the value of capital for each firm to grow by the rate of growth that they have exhibited over the period of study for each firm. Sensitivity analysis results are shown in Table 4.

Table 4. Average Rate of Growth of Output Under Two Hypothetical R&D Expenditure Scenarios

Scenarios of firm-level R&D expenditure	*Doubled*	*Tripled*
Average growth of log real output (%) with R&D lagged 1 year (equation 2)	0.11	0.18
Average growth of log real output (%) with R&D lagged 2 years (equation 3)	0.04	0.15

Source: Author's calculation based on estimated equations (2) and (3).

We note from Table 4 that the doubling and tripling of firm-level R&D with a one-year lag yields higher growth rate in output than the respective expenditure with a 2-year lag. We further note that the magnitude of potential growth rates reflected may be small owing to low R&D expenditures across all firms in the data set as highlighted earlier.

IV. POSSIBLE EXPLANATIONS FOR WEAK R&D PERFORMANCE IN EGYPT

In this section, we attempt to provide some explanations for the statistical insignificance of the R&D variable in the estimated equations, or for the low value of the lagged R&D coefficient. We draw on the explanations forwarded in the literature as discussed in Section III (previously classified as pertaining to the macro- or micro-levels).

[27] Lagged R&D expenditure is used in many studies but there is no agreement on the correct length of lag (Wakelin 2000:7). For perspective, Griliches and Mairesse (1985) use a 3-year lag in R&D, while Scherer (1982) uses a 4 to 6-year lag length (Scherer 1982:629).

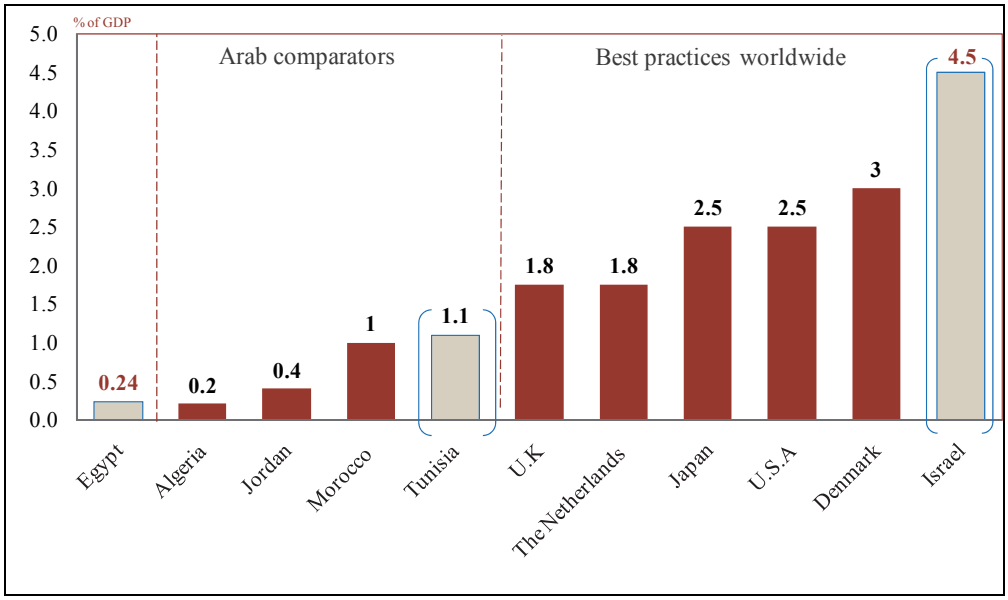
IV.i. Macro-level Explanations

To provide evidence as to whether some of the macro-level explanations are relevant to Egypt's case, we give an overview of R&D expenditure economy-wide, the overall organizational structure of public R&D in Egypt, and draw on Egypt's performance on the various dimensions of the innovation pillar[28] of the Global Competitiveness Index (GCI).

Low economy-wide expenditure on R&D

Over the period 2000-2009, Egypt's average economy-wide (public and private) R&D expenditure as a percentage of GDP is 0.24 (calculated from World Development Indicators (2012); and Egypt's Ministry of Higher Education and Ministry of State for Scientific Research in CAPMAS (2011b)[29]). It is lower than the period average (in percent) for comparator Arab countries in the Middle East region and best practices worldwide (Figure 2).

Figure 2. R&D Expenditure: Arab Comparators and Best Practices Worldwide (Average 2000-09)



Source: Calculated from the World Bank "World Development Indicators."

[28] One of twelve pillars of the GCI.

[29] Ministry of Higher Education and State for Scientific Research reports the following percentages for R&D expenditure relative to GDP for the years 2003/2004 through 2006/2007: 0.27; 0.25; 0.26; 0.23(*Source*: CAPMAS 2011b).

Low capacity to translate R&D expenditure into output or productivity gains owing to an inadequate organizational structure

Organizational structure is broadly defined as the manner in which roles and responsibilities are coordinated and controlled. It also relates to the flow and management of information. At the macro-level, we need to look at the structure of the national system[30] that sponsors scientific R&D in Egypt.

The respective system is comprised of institutions belonging to the sectors of *higher education, production* and *services*. Under *higher education* comes the Ministry of Higher Education (which, in turn, covers public universities with their affiliated research centers), and the Ministry of State for Scientific Research (covering large research institutions such as the National Research Center). Under *production* and *services* lie the various ministries with their affiliated research centers[31] (OECD and World Bank 2010).

As such, public research institutions undertaking R&D in Egypt are fragmented across the production and service sectors, universities, and others. All these entities work within different organizational and administrative settings, are bloated with a large number of R&D personnel, funded under dissimilar rules, lack coordination among themselves, and lack internationally-recognized standards and criteria for measuring their R&D output. Also, in the absence of a coherent framework for planning, funding and accountability, it becomes increasingly difficult to coordinate between the various institutions. The overall governance structure of the public R&D system in Egypt is thus described as "bureaucratic and bloated" (OECD and World Bank 2010:236-37).

Further under organizational structure, we note that Egypt's public R&D priority lies with the Ministry of Higher Education, followed by the production sectors of agriculture and petroleum, and the Ministry of State for Scientific Research. In 2010 the share of those working for the institutions affiliated with the above entities in the total number of public R&D personnel economy-wide is: 42 percent for the Ministry of Higher Education; 20 and 18 percent for the production sectors of agriculture and petroleum, respectively. The Ministry of

[30] In 2007 the Egyptian government developed the system to include the Higher Council of Science and Technology and the Science and Technology Development Fund (both established through the passing of two presidential decrees). Public funding of R&D projects therefore comes from both the Ministry of Finance and the Fund.

[31] Production sectors cover the ministries of industry and trade, petroleum and minerals, agriculture and land reclamation. Service ones cover the ministries of electricity and energy, housing, transportation, health, social affairs, irrigation, planning and labour (*Source*: OECD and World Bank 2010:222).

State for Scientific Research (with its large affiliated research center(s)) has a 6 percent share. Among the services sector, the centers affiliated with the Ministry of Health is 1 percent (calculated from CAPMAS 2011b). Although the research agenda of the State Ministry of Scientific Research includes areas of bio- and nanotechnology, as well as others with relevance to pharmaceuticals, yet the share of the Ministry of Health still appears relatively modest.

To sum up, the organizational structure of the public R&D system in Egypt does indeed appear to be inadequate for translating R&D expenditure into output or productivity gains. The structures of corporate governance are also unsuitable for that purpose.

Low R&D personnel intensity and other macro-level explanations as evident from the GCI

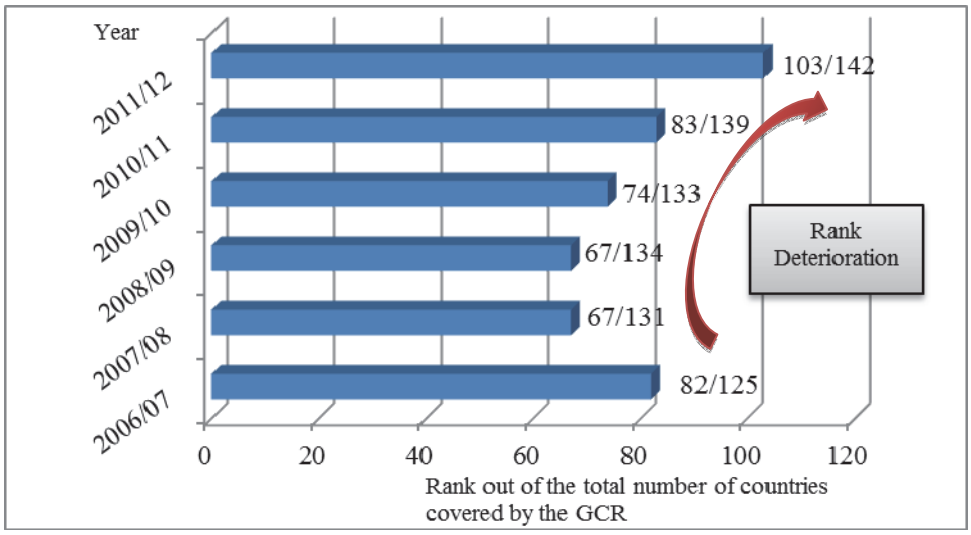
A number of the other macro-level explanations forwarded in the literature and reviewed above (e.g., the supply of scientific and technical labour and weak university-business links,) are, in fact, among the dimensions of the innovation pillar of the GCI. We start with an overview of Egypt's performance on the overall pillar and then zoom in on its dimensions to identify problem areas.

Figure 3 shows Egypt's rank on the innovation pillar over the period 2006/2007-2011/2012. The analysis commences with the year 2006/2007 because it marks the first year in which 'innovation' appears as an individual pillar per se in the GCI. Before that date, some of the dimensions which now make that pillar[32] were scattered across the 'business competitiveness' and 'technology' pillars.

As evident from the Figure, Egypt's rank on innovation has deteriorated progressively over the period 2007/08–2011/12.

[32] Namely: capacity for innovation; quality of scientific research institutions; company spending on R&D; university industry collaboration in R&D; government procurement of advanced tech products; availability of scientists and engineers; utility patents granted per million population (this being the only dimension in this pillar which is based on hard data not derived from the Executive Opinion Survey).

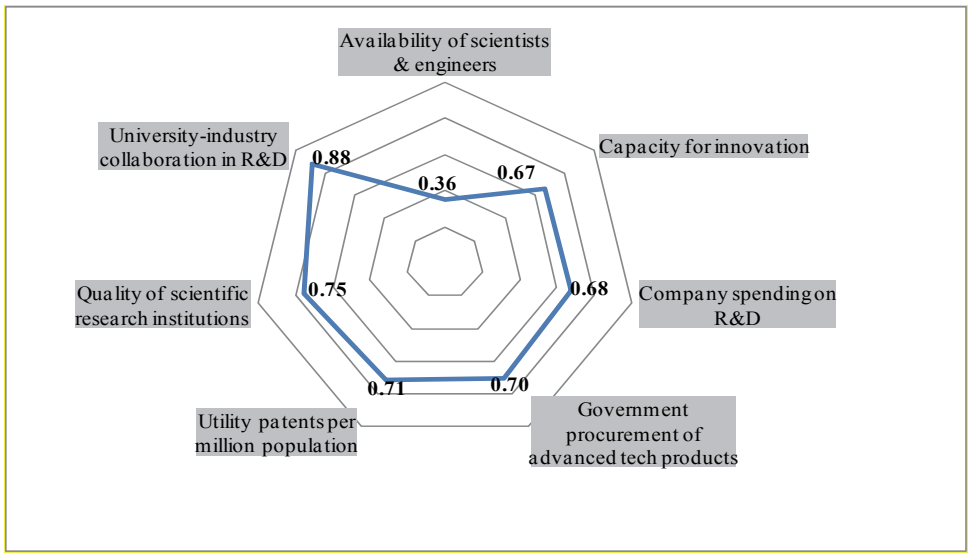
Figure 3. Egypt's Rank on the Innovation Pillar (2006/07– 2011/12)



Source: Compiled from WEF Global Competitiveness Report (GCR), various issues.

Zooming in on the dimensions, we looked at the average of 'ranks attained on each of the seven dimensions of the pillar *relative* to the total number of countries included in each year's GCR over the period 2006/2007-2011/2012. A 'low relative rank' signals that a country ranks high on the list of countries included in the GCR. Hence, the closer is the relative rank to the center of the radar chart, the better off a country fares on the respective dimension of innovation (see Figure 4).

Figure 4. Relative Ranks on the Dimensions of Innovation (average 2006/2007-2011/2012)



Source: Author's calculation based on WEF GCR, various issues.

Two points are worth noting from the above figure: 1) clockwise, Egypt fares best on *the availability of scientists and engineers,* and worst on *university-industry collaboration in R&D;* 2) from the second best-performing dimension *(capacity for innovation)* to the worst-

performing one, Egypt's performance is, in fact, quite modest—falling in the lowest third bracket of countries.

A closer look at the above dimensions in terms of their degree of variability (assessed through the standard deviation (σ) and coefficient of variation (v) of the relative ranks attained over the period) shows that even the best-performing dimension exhibits an erratic behaviour over time (see Table 5). The modest performance of the remaining dimensions is further compounded with similar inconsistency.

Table 5. Variability of Relative Ranks on the Dimensions of Innovation (2006/2007-2011/2012)

Dimension of Innovation (*best* to *worst* performing)	σ	v	Rank of dimension by 'v'
Availability of scientists and engineers	**0.08**	0.224	(1)
Capacity for innovation	**0.07**	0.11	(5)
Company spending on R&D	**0.15**	0.216	(2)
Government procurement of advanced tech products	**0.11**	0.16	(3)
Utility patents per million population	**0.06**	0.08	(6)
Quality of scientific research institutions	**0.04**	0.05	(7)
University-industry collaboration in R&D	**0.12**	0.14	(4)

Source: Author's calculation based on WEF GCR, various issues.

To sum up, in contrast to the explanation forwarded in the literature, our findings indicate that the supply (availability) of scientific and technical labour may not, in itself, contribute to weak R&D performance, but rather its inconsistency.[33] Moreover, in line with the above analysis on 'organizational structure,' Egypt's R&D performance also appears to be held back by weak university-business collaboration in R&D and modest quality of scientific research institutions, both with implications for a 'low' overall capacity for innovation.

Lack of fiscal (or financial) incentives for R&D purposes

Corporate fiscal incentives for R&D purposes include tax allowances/credits. Tax allowances allow a firm to deduct from its taxable income either the current[34] or the full R&D expenses. Egypt's Income Tax Law No. 91/2005 does not include any such allowances or credits. Article (23) of the law merely allows a firm to deduct from its taxable income any donations made to Egyptian scientific institutions[35] (Ministry of Finance 2005).

[33] As recorded from the responses obtained from the Executive Opinion Survey. One possible explanation for such inconsistency may be the brain drain.

[34] Namely, costs of energy and materials used for R&D, in addition to the cost of subcontracted research.

[35] Provided such donations do not exceed 10 percent of the taxpayer's annual net profit.

Financial incentives for R&D purposes include the government's subsidizing of the exchange of R&D personnel between public and private sectors, the encouragement of joint public-private collaboration in R&D projects, and the competitive provision of direct funding to firms through R&D grants and soft loans (e.g., as practiced in Italy and New Zealand (OECD 2002:11)). However, Egypt's meager macro R&D expenditure, as highlighted earlier, is expected to curtail the government's ability to provide such incentives.

Other government-sponsored financial measures include the creation of specialized financial market mechanisms such as venture capital for R&D purposes (Mani 2005:3). Although Egypt fares moderately well on the availability of venture capital, in general,[36] it still lacks venture capital for R&D purposes. Worldwide (e.g., in the U.S. and Canada), venture capital is used as a tool to support R&D endeavours especially in new firms and start-ups (Hall and Lerner 2009:24).

Poor utilization of the system of intellectual property rights

The *absence or poor utilization of the system of intellectual property rights* tends to shake the confidence of firms in appropriating the returns from their R&D investment, thus de-incentivizing further investments. In 1995 Egypt joined the TRIPS agreement, although its commitments were to be effective 2005 (at the end of a 10 year grace period). In 2002 Egypt passed a new IPR law (82/2002) which, unlike the old law, extended patent protection to both processes and products. The law was also closely aligned to Egypt's TRIPS obligations.[37] This would suggest that a relatively well-grounded system of intellectual property is in place, thus refuting the argument that the absence of such a system may contribute to weak R&D performance.

IV.ii. Micro-level Explanations

To verify whether the micro-level explanations cited in Section III are relevant to the case of pharmaceutical firms in Egypt, we conducted 5 in-depth interviews. Questions addressed in the interviews were taken from the annual "Business Research and Development and

[36] On a score range of 1= minimum venture capital availability and 7= readily available venture capital, Egypt scored 3 in 2011/2012 with a rank of 41/142 (WEF 2011-2012:169).

[37] For example, the law allowed for parallel imports produced under compulsory license, in addition to granting a drug protection period of 20 years from the date of filing for the patent application in Egypt (all in keeping with TRIPS agreement).

Innovation Survey" administered by the U.S. National Science Foundation.[38] They aimed to shed light on firm-level R&D performance and innovation from the following angles: R&D expenditure; the introduction of *new* and *improved* products and processes; the nature of research carried out; human resources engaged in R&D; patents and intellectual property.

Optimally, we would have liked to select firms for interviews based on their R&D expenditure. However, in the absence of published firm-specific R&D data,[39] we adopted a host of selection criteria, which include ownership structure (see the Appendix for further details). One firm was chosen from each of the following ownership categories: privately-owned (PR), publicly-owned (PB), joint private and public Egyptian capital (PRPB); joint private Egyptian and private foreign capital (PRPB), and wholly-owned subsidiary of a multinational corporation (MNS). In order not to disclose their identities, firms will be denoted by the abbreviations shown between parentheses.

Low firm-level expenditure on R&D

PR, PRPB and JV assessed their average R&D intensity (expenditure relative to total sales revenue) to be in the range of 1-2 percent, while that of PB was 3-5 percent. The figure reported for PR appears in line with a 1.5 percent average private sector pharmaceutical R&D intensity reported for Egypt's industry, while that of PB is much higher than the 0.7 percent for public sector firms (Subramanian and Abdel-Latif 1997:11(Table 6)).

Firm-level pharmaceutical R&D intensity in Egypt is indeed quite low when compared to worldwide practices. For perspective, the National Science Foundation estimates average annual R&D intensity for U.S. pharmaceutical firms to be around 8-10 percent (CBO 2006:9). As such, R&D does not appear to rank high as priority expenditure for Egypt's firms. The interviews have further indicated that low intensity may relate to the way firms annually budget for their R&D, and/or to the accounting practices they adopt.

On the one hand, all interviewed firms (except MNS)[40] confirmed that their annual R&D budgetary allocations were based on their research plans for the upcoming year, as opposed to a given percentage of their estimated sales revenue. These plans were mostly

[38] Administered annually and reputed to provide a comprehensive coverage of R&D-related issues: nature of research carried out by firms; expenditure on R&D; R&D human resources; intellectual property and technology transfer.

[39] Whereby such expenditure is not revealed in income statements.

[40] Being a subsidiary, it does not hold an R&D budget separate from that of the mother company. Similarly, Subramanian and Abdel-Latif 1997 report no R&D intensity for MNCs (Subramanian and Abdel-Latif 1997:11(Table 6)).

driven by operational needs, and not by a well-defined prospective research agenda. Therefore, R&D expenditure tended to be mostly development oriented (as per the definition of R&D given in the introduction).

On the other hand, the interviewed firms also confirmed that their R&D expenditure is primarily on material for laboratory use, instruments and equipment for R&D-related projects, and did not cover the salaries of R&D personnel. Under the accounting practices adopted worldwide, firms differentiate between R&D expenditure of the 'current' and 'capital' types, with current costs covering both personnel and materials used in R&D, while capital ones cover R&D-related instruments, equipment, land, buildings, and computer software (UNESCO 2008:6). Hence, low R&D intensity of Egypt's firms may partly owe to the accounting practices they adopt vis-à-vis their international counterparts.

Low capacity to translate R&D expenditure into output or productivity gains owing to an inadequate organizational structure

The definition of organizational structure given earlier also applies at the firm-level. However, we add that the flow and management of information may be both intra- and inter-organizational (i.e., between the firm and its suppliers, or other entities with which it establishes an information network, e.g., research centers (Braha and Bar-Yam 2004)). In so far as evident from the in-depth interviews, we use firms' responses to shed light on how some aspects of their organizational structures may influence their capacity to translate R&D into output or productivity gains.

In an R&D context, the definition of organizational structure with reference to roles and responsibilities within the firm may relate to the intensity of R&D personnel. However, this aspect is separately dealt with later in this paper. In this section, we explore other aspects which are linked to intra- and inter-organizational management and flow of information: 1) the nature of R&D that firms undertake; 2) their scope for collaboration in research with other firms or research centers, 3) their scope for collaboration with other firms in intellectual property.

In reference to the *nature of R&D*, interviewed firms showed no substantial evidence of conducting either *basic* or *applied* research. They also showed no evidence of conducting research involving bio- and nanotechnologies.[41] Their R&D efforts thus mainly focused on

[41] Only PRPB attested to some future plans to employ nanotechnology in the dissolution of tablets.

clinical trials[42] (which come under the *development* component of R&D).[43] However, they noted that they only conducted certain types of clinical trials in-house (like bioequivalence studies, stability tests or post-marketing surveillance), meanwhile commissioning the rest to accredited[44] research centers affiliated with public universities (e.g., Cairo, Ain Shams, Tanta, among others).

The absence of basic and applied research in the interviewed firms may also relate to the fact that they (like the majority of Egypt's pharmaceutical firms) produce either off-patent generics, drugs under license, or drugs invented prior to 1995 (hence not subject to TRIPS). As such, they may not have the incentive to conduct the type of research that yields new products or processes, leaving them more oriented toward the *development-type research.* In this respect they lag behind worldwide practices. Although the latter do not preclude clinical trials as part of the development component of their R&D, they lean heavily towards *basic* and *applied* research, with an important bio- and nanotechnology component. Thereby, they are primarily oriented to *pursuing new knowledge*.

As for *inter-firm collaboration in research*, firms may vertically collaborate with their upstream suppliers or horizontally with their competitors so as to address particular research areas. They may also establish cost-sharing R&D agreements, or form strategic alliances and peer-firm-consortia specifically for R&D purposes.[45] In contrast to worldwide practices, none of the interviewed firms cited inter-firm collaboration in research of this nature.

Under *firm-university collaboration in research*, firms may provide funds or grants to university research centers for undertaking research projects, or both parties may undertake them jointly. Either way, firms stand to benefit from potential cost reduction as universities possess large economies of scale and scope in R&D. No such evidence was found in the interviewed firms. At best, they sought the consultancy of state university academics for specific research tasks,[46]or they provided free drug quantities to public- and private-

[42] Such trials primarily aim to assess the effectiveness and/or dosage of a drug in the treatment of an illness. They may involve patients, healthy individuals, or both.

[43] As per the definition of R&D presented in the introduction, CBO 2006:2, and Subramanian and Abdel-Latif 1997:13.

[44] Accreditation is provided by the Ministry of Health.

[45] Such consortia aim to avoid duplication of R&D efforts, to share results in a cost-effective manner, and to pool talent and expertise.

[46] Firms across PR, PB and PRPB reported such instances.

university research centers, physicians or doctoral candidates.[47] Again, such practices fall short of worldwide firm-university collaboration.

Inter-firm collaboration in intellectual property often involves contractual arrangements of the 'technical cooperation' or 'technology exchange' types. Under technical cooperation, firms may conduct joint research in order to share costs, to reduce uncertainty, and to create economies of scale and/or scope that will facilitate their coverage of a wider field of research or expand their competencies (Hagedoorn 1993:373). Under technology exchange arrangements, firms may undertake 'know how' or 'cross licensing' agreements. Respectively, these agreements enable them to access much-needed know-how without necessarily being a licensee of the product[48] or to enjoy mutual access to the licenses held by one another without paying due license fees. Interviewed firms in Egypt showed no evidence of taking part in any such arrangements.[49]

Literature associates adequate organizational structure with the firm's propensity/capacity to innovate (Lam 2004:3-5). Such propensity is broadly measured by firms' ability to introduce (or pioneer) their own *new* or *improved* products and processes relying on own formal research (WEF 2011-2012:13). As evident from the above discussion, firms do not appear to possess the organizational structure required to support output and productivity gains. This, in turn, implies that their propensity to innovate may be limited (as discussed below).

Narrowly speaking, neither *new products* nor *processes* were introduced by the interviewed firms, because *new products* entail, for example, the discovery of new molecule(s), while *new processes* entail employing some new drug manufacturing method. Interviewed firms showed evidence of neither. Furthermore, we note it is quite unlikely that

[47] University research centers and physicians were often interested in conducting clinical trials or testing the effectiveness of using the drug to treat some illness other than what the drug is originally administered for. Similarly, upon request, doctoral candidates were given free drug quantities for trial and experimentation purposes.

[48] Such as the formulae, charts, drawings, process sheets, standards and other information deemed necessary to understand and utilize the specific know-how.

[49] That is not to say, however, that firms were not producing products under license. In fact, both PR and PRPB were licensees of products owned by large corporations like Heindrich-Mack and Abbott, acknowledging that this serves as an important means of acquiring know-how, albeit in exchange for a license fee.

their meager R&D expenditure (as indicated above) can support the huge cost of introducing new products[50] and processes.

We found evidence, however, of firms introducing *improved products and processes*. Some firms modified an old registered drug and launched it in new form, e.g., from pill to syrup form, meanwhile confirming that making mere aesthetic changes to packaging (or the like) would not qualify them to have introduced *improved* products. In their words, *improvements* had to bring about fundamental changes to form or efficacy. We also found evidence of firms implementing *improvements to their processes, logistics and support activities*, e.g., PR and PRPB introduced new production lines and/or upgraded existing ones,[51] while PRPB and MNS implemented 'good manufacturing', in addition to 'good distribution and storage' practices.[52] G*ood pharmaceutical practices* generally relate to quality- and process-related principles that must be observed during manufacturing, distribution, storage and logistics.

Worthy of note, however, is that the interviewed firms expressed their concern that regulations sometimes hinder them from tapping into product improvements. As many of them produce off-patent generics, the Ministry of Health permits them to register a generic drug if, and only if, it has an exact counterpart in reference countries (in dosage form, all product characteristics, as well as exact matching of the enclosed drug leaflet). They expressed further concern over the fact that the Ministry of Health conditions the registration of a drug on the availability of a vacant slot in its so-called "box". With the box holding only limited slots per product category, registration is often denied.

The nature of R&D undertaken by the interviewed firms indicates that they are short of the organizational structure required for translating R&D into output or productivity gains. This is evident in the limited scope for both inter-firm and firm-university collaboration in research. It is also clear in the limited scope for inter-firm collaboration in intellectual

[50] The average cost of developing an innovative new drug is estimated to be $800 million. This cost includes the cost of research, expenditure on failed products and value of foregone alternative investments. Such a cost is expected to be realized over a period of 10-12 years (CBO 2006:2).

[51] PR also mentioned improving the air handling units all with direct bearing on quality, while PB introduced a line that compresses and packs effervescent tablets in one process.

[52] As for support activities, all five firms had either developed their purchase and accounting practices, or linked up with other branches or sister companies. For example, PR introduced SAP (systems applications and products), PB linked together a number of affiliates (of the Holding Company for Drugs) through a common system that renders better pre-manufacturing planning, while JV implemented an internal audit control system even though it was not mandatory to do so.

property and weak propensity to introduce new products and processes. All reflects on their limited tendency to innovate.

Low capacity to translate R&D expenditure into output or productivity gains owing to low R&D employee intensity and insufficient level of skills

R&D personnel intensity (employees working in R&D relative to total employees) in the interviewed firms was in the 1-2 percent range. Indeed, such intensity falls short of worldwide ones. For example, pharmaceutical R&D personnel intensity in some of new EU member states in the year 2007 was as follows: Slovakia 3.0 percent; Poland 3.8; Romania 4.1; and Czech Republic 5.3 percent. Figures for older member states falling at the higher end of the spectrum of pharmaceutical R&D personnel intensity are the Netherlands and Denmark (27.4 and 26.3 percent, respectively (Eurostat 2008)).

In spite of the low R&D personnel intensity, interviewed firms did not view their personnel to be lacking in skills. The majority of their R&D personnel were scientists/pharmacists/chemists, the rest being technicians. JV had one holder of a Ph.D. degree and another holder of M.Sc. degree, while MNS had one of the latter.

Except for MNS, none of the interviewed firms cited hosting post-doctoral research fellows. Other practices fostering the exchange of know-how (e.g., sending scientists abroad for specific research missions) were not common either. In reference to worldwide practices in this regard we note that India's pharmaceutical firms are reputed to host post-doctoral research fellows and to send R&D personnel for training and knowledge-acquisition in the U.K. and U.S.A.

In essence, although lack of skilled R&D employees does not constitute a problem for the interviewed firms, their overall R&D employee intensity appears low. Coupled with the absence of practices fostering the exchange of know-how, this may bear negatively on their capacity to translate R&D expenditure into output or productivity gains.

V. CONCLUDING REMARKS

Macro-level issues with relevance to R&D in the case of Egypt have been found to vary from a very modest public R&D expenditure, *to* the need for a well-defined medium-to-long national research strategy, lack of good governance of the public R&D system in Egypt, lack of coordination between public institutions and businesses, as well as lack of fiscal and financial incentives to R&D, in addition to an inconsistency in the availability of scientists

and engineers. These issues are almost completely mirrored at the micro-level. We probe the macro and micro-relevant policy implications in what follows.

Low public R&D expenditure makes it imperative that Egypt raise its public R&D expenditure. In addition to furthering knowledge creation at the level of public research entities, higher expenditure should also create space for R&D grants and soft loans to be allocated to large and small private sector firms, enabling government support of firm-level R&D.

Indeed, Egypt is often criticized for still being in need of a well-defined medium-to-long term national strategy for R&D—one that includes both public and private sectors and spans the whole range of economic activities. With reference to pharmaceuticals, this activity does not appear to rank high on Egypt's research priorities as evident from the share of those working in research institutions affiliated with the Ministry of Health in the total number of public R&D personnel (1 percent in 2010). Recognition of the role of R&D in driving this industry's growth, as was evident from comparable country experiences, should help direct Egypt's government to rank this industry high on its R&D priority list.

At present, the R&D system is described as "bureaucratic and bloated," lacking sound coordination of the R&D efforts of public institutions with many instances of duplicated and redundant efforts. It remains of great importance that Egypt's R&D strategy spell out a division of responsibility among public research institutions, together with having a good governance structure with adequate monitoring and evaluation mechanisms in place.

As for the coordination between public institutions and businesses, the national strategy needs to strengthen university-business links to ensure that public research is demand-driven. Moreover, once public funds are available for R&D efforts of large and small firms, their allocation must be competitive-based. These two issues were, in fact, targeted by three R&D initiatives begun by Egypt's government in 2007. They included the establishment of: the Higher Council for Science and Technology; the Science and Technology Competitive Fund; an R&D programme in cooperation between the Ministry of State for Scientific Research and the European Union (with an €11 million grant).[53] The three initiatives simultaneously aimed for a demand-driven public research and the promotion of competitive-based R&D

[53] The programme is comprised of three components: The EU-Egypt Innovation Fund, which includes two grant schemes to 'large' and 'small' projects aiming to promote innovation in products, processes and services; Research, Development and Innovation Network for the networking universities, public research institutions and firms in order to strengthen links among institutions and also between institutions and business sector; and initiatives for the monitoring and evaluation of institutions funded under the programme.

funding[54](OECD and World Bank 2010:239). With five years elapsing, the initiatives still do not appear to have borne fruit.

From an industrial policy standpoint, Egypt's government must attempt to initiate some viable fiscal incentives such as tax allowances to promote R&D. The present income tax law includes no allowance of this nature. The government may also consider introducing financial tools such as venture capital for R&D. Various venture capital practices are presently in place but none are earmarked for R&D.

Firm-level evidence also points to firms facing various legislative constraints. With many of them producing off-patent generic drugs, they indicated that the Ministry of Health permits the registration of a drug only if it is an exact replica of its counterpart in reference countries (i.e., dosage, characteristics and even the leaflet enclosed). Such legislative constraints hinder firms from innovating on existing generics. It may be advisable to revisit such legislations in a way that addresses firms' concerns.

Although our analysis indicates that Egypt is not short on the availability of scientists and engineers, there is an inconsistency in their supply (as detected from the variability in the dimension related to the availability of scientists and engineers in the GCI). One explanation may be the brain drain. Although discussion of policies to mitigate the problem of brain drain is beyond the scope of this paper, we note that Egypt may promote a steady supply of scientific and technical labour, thus mobilizing resources for R&D, through encouraging the study of science, mathematics and engineering to increase graduates. Egypt's university graduates are heavily concentrated in 'humanities and social sciences' as opposed to 'science and engineering' (in 2010/2011, 80 percent of higher education graduates were in the humanities and social sciences versus 20 percent in sciences and engineering[55] (calculated from CAPMAS 2011a:321,327)). Thus, reform of the education system should aim at balancing skills on the supply side with demand priorities in the labour market.

The in-depth interviews have made it evident that the need for a well-defined national R&D strategy is not a macro-level symptom alone, but also a micro-level one. As such, firms tend to undertake piecemeal projects addressing practical or operational problems with no vision of long-term research. This has a bearing on their R&D expenditure being relatively

[54] In addition to the enhancement of participation of Egyptian research institutions in the European research area.

[55] Please note that humanities and social sciences are included in the yearbook as "theoretical faculties" versus sciences and engineering included as "practical faculties".

modest and inconsistent year-after-year, as well as on their research being mostly of the *development* as opposed to *basic* or *applied* types. It further reflects on their lack of interest to commission projects to universities or to undertake them jointly, as well as their having virtually no scope for inter-firm collaboration in research or in intellectual property. Their overall propensity to innovate remains limited with no introduction of new products or processes, but only some improved ones.

In short, firms appear to lack the organizational structure required for translating R&D into output or productivity gains. In this sense, it would be difficult to draft a direct prescription for pharmaceutical firms in Egypt. We may, however, forward some advice inspired by the in-depth interviews. *First*, firms would be well-advised to incorporate an R&D expenditure item in their income statements to facilitate access to their R&D expenditure data. *Second*, they may choose to promote the exchange of their R&D personnel for greater knowledge acquisition. *Finally*, we leave firms with the following note: *it is through recognition of the true growth potential associated with R&D that they may deepen their R&D practices in the interest of better R&D performance.*

APPENDIX: CRITERIA FOR SELECTING PHARMACEUTICAL FIRMS FOR IN-DEPTH INTERVIEWS

In a study of this nature, pharmaceutical firms would have typically been selected for in-depth interviews based on the level of their R&D expenditure. However, due to the absence of published annual firm-specific R&D expenditure data,[56] firms were selected based on ownership structure, market share, market capitalization at end of November 2011 (for those whose stocks are traded on Egypt's Stock Exchange), range of export markets, size of employment and contribution to the total employment of the pharmaceutical industry. Ownership structure ranges from: private firms operating under the 'Company Law 159/1981'; public sector firms operating under 'Public Sector Law 203/1991'; firms of joint public and private Egyptian equity operating under 'Public Sector Law 203/1991'; firms of Egyptian and foreign private capital operating under 'Investment Law 8/ 1997'; wholly-owned subsidiaries of multinational corporations (MNCs) operating in Egypt under 'Investment Law 8/1997'.

Data on the above indicators used for selection were compiled from Kompass Egypt Financial Yearbook 2010/2011, Egypt Stock Exchange website (at www.egx.com.eg), the Annual Industrial Survey issued by CAPMAS, and Intercontinental Marketing Services 2002. We initially located the following number of firms: 6 private (PR); 1 public-sector (PB); 5 joint private and public Egyptian ownership (PRPB); 6 joint private foreign and Egyptian ownership (JV); 9 MNC subsidiaries (MNS). Naturally, this is not an exhaustive coverage of all firms operating in the industry, but rather those firms for which data was accessible and which fell under all the ownership structures identified earlier.

We arranged firms in each category based on the highest market capitalization, market share, contribution to pharmaceutical industry employment, and the widest range of export markets. The R&D-related issues probed in the interviews can be broadly grouped into: introduction of new (or improved) products and/or processes; nature of research carried out and expenditure on it; strategy for R&D; human resources engaged in R&D; patents and intellectual property.

[56] Whereby such expenditure is not revealed in income statements

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