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Absorptive Capacity of Human Capital and International R&D Spillover on Labour Productivity in Egypt

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Introduction

The theoretical and empirical economic literature provides evidence that knowledge transfer between countries or regions has contributed to the productivity growth of other geographic areas (see Coe and Helpman 1995; Coe et al. 2009; Kao et al. 1999; Litchtenberg and Brouno 1998).

In addition, empirical evidence has been also presented with respect to the direction, the magnitude and the effectiveness of different channels through which such spillover effect is transmitted.

However, few studies have examined the effect of international R&D spillover transmission from industrial countries to developing countries. Those that have been conducted in this respect focused on the macro

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level and the overall effect on total factor productivity. Very few empirical studies have been conducted on how international R&D spillover affects labour productivity in developing countries.

The main objective of this chapter is to survey the literature on international R&D spillover transmitted from industrial countries to developing countries and its effect on labour productivity, then to build a model whose basic assumption suggests that, technology and innovation can be transmitted to the Egyptian manufacturing industries through various channels. However, the effect of international R&D spillover can be insignificant in enhancing labour productivity if there is a low absorptive capacity of human capital.

Hence, the chapter will examine the relationship between the labour productivity of the Egyptian manufacturing industries, relative to international R&D capital stock, and human capital.

The chapter is organised as follows: the second section discusses the literature pertaining to international R&D spillover and how it affects productivity in developing countries. The third section outlines the methodology and model application, using time series analysis to examine the effect of international R&D spillover and school enrolment on labour productivity in the Egyptian manufacturing industries. The fourth section analyses estimation results and interpretations. The final section concludes with the main findings and recommendations of the research.

Literature Review

International R&D was originally discussed in several studies, the most significant being Coe and Helpman (1995) (as cited from Coe et al. 2009). They contributed new estimates of R&D spillovers that differed from those of earlier research studies, which only examined spillover across sectors or industries for a single country.

Their estimates of R&D spillovers used a pool of macroeconomic data for 21 OECD countries plus Israel over the period 1971–1990. They estimated the relation of a country's total factor productivity as a function of the domestic research and development capital stock and foreign R&D capital stock as a proxy for the stock of knowledge embodied in a country's trade position. All the measures of foreign and domestic research and development capital were constructed from the business sectors' research and development activities.

The model used the estimated elasticity of total factor productivity in relation to domestic and foreign R&D capital stock. In another study, Coe et al. (1997) estimated elasticity of the total production function in relation to the change in domestic and foreign R&D capital stocks, imports of machinery and equipment, and secondary school enrolment ratio. Another contribution of the Coe and Helpman model (1995) is using this function as empirical evidence that research and development spending in industrial countries can be transmitted to developing countries and increase these countries' total productivity.

Many studies advocated this model but using advance statistical techniques. Coe et al. (2009) adopted the modern panel cointegration method that was not available in the early 1990s. In addition they did an expansion of the panel to the same model.

Another study by Kao et al. (1999) used the same model and adopted methods of OLS, FM and DOLS estimators in panel data. The study concluded that the estimated coefficients in the Coe and Helpman model (1995) are subject to estimation bias, but they have correct signs. However, the results support the argument for international R&D spillover.

Litchtenberg and Brouno (1998) examined two important characteristics of the Coe and Helpman model (1995). Firstly they argued that the foreign R&D weighting scheme suffers from 'aggregation bias' and suggested a less biased weighting scheme. They also corrected an indexation bias and found that the more a country enjoys trade openness, the more probability of gains from R&D spillover.

Muller and Michaela (1998) argued that the choice of an appropriate model for behaviour of panel data can affect the results of the Coe and Helpman model (1995), in other words, the choice between fixed coefficient methods previously used in the model and the use of a random coefficient model in this study. Applying the model using fixed regression gave unreliable results when compared to random coefficient analysis results.

The channel through which international R&D is transmitted was debated in several studies on the macro level (across borders of countries) and on the micro level (across firms or industries in the same country).

Cincera and Bruno (2001) distinguished between rent spillover of technology transfer that occurs from trading transactions of factor imports and machinery that embodies innovative technology on the one hand, and international knowledge spillover across countries via foreign direct investment, international research collaboration, scientific publications or brain drain on the other hand. Both are difficult to measure due to high collinearity between them. Wolf and Ishraq (1993) depicted a channel of R&D spillover embodied in new investments that enter a sector in the economy.

The absorptive capacity of a recipient country for international R&D spillover was taken into consideration when analysing the magnitude of impact on productivity. Several determinants of absorptive capacity were suggested in various studies.

The first is the quality of human capital as an important catalyst for absorption (Sunkwark and Young 2006). They built their assumption on the idea that domestic human capital is an important factor in understanding the foreign high technology embodied in imported goods and absorbing it for domestic use. McNeil (2007) specified the quality of the labour force and capital accumulation as two vital determinants of absorptive capacity of spillover.

The second is the technology gap between countries, where studies questioned the impact of international R&D on total factor productivity with a wide technology gap in developing countries (Blomstrom and Kokko, as cited from Bouoiyour 2005).

Zhu and Bang (2007) showed that innovation in information technology has played a significant role in facilitating the transmission of international R&D spillovers among OECD countries and Israel and consequently improving productivity growth.

Finally, Coe et al. (2009) added a group of institutional determinants which impact the absorptive capacity of international research and development spillover in recipient countries. These include the ease of doing business, the quality of the tertiary education system, the strength of patent protection laws in the country and their effectiveness in copyright protection, and the origin of the country's legal system. All these determinants were found to be highly correlated to the improvement of total factor productivity through enhancing the absorptive capacity of spillover.

Other contributions were made to the literature of international R&D spillover by examining its impact on other economic variables. Costa and Stefano (2004) focused on the effect of technology innovation spillover on economic growth. They made use of the dynamic growth model, which facilitates the evaluation of regional convergence and innovation on long-run labour productivity, without the technology index that is usually used in the technology gap model for developing countries.

Borras, Serrano and Simarro (2011) examined the effect of intersectoral direct and indirect knowledge spillover on a sector's labour productivity on a disaggregated level. Their interpretation of knowledge included innovation, research and development, and tacit knowledge.

Gera, Wulong and Frank (1999) presented an empirical model that estimates the effect of information technology investments and R&D spillover from the information technology sector on labour productivity between Canadian and US industries. They relied on the Coe and Helpman (1995) model for estimating foreign research and development capital and domestic research and development capital. They agreed on the transmission channels introduced in this model. However, they regressed the annual average labour productivity rate of an industry on the information technology and non-information technology investments for five sub-periods from 1971 to 1993. They regressed the mean values of the research and development variables over the same results.

Their result showed a significant effect of international R&D spillover from information technology sectors on labour productivity for both sectors, with low significance from non-information technology sectors.

Empirical studies of international R&D in relation to total factor productivity in few Middle East countries like Morocco and Egypt were conducted but with a narrow scope. McNeil (2007) examined the effect of international R&D spillover on total factor productivity through its diffusion in the intermediate products imported from OECD countries to the Egyptian and Moroccan manufacturing sectors. He used the same model which Coe and Helpman model (1995) have used. In addition, his study showed the significance of cross-border research and development spillover on total factor productivity, where Human capital, is a core determinant of the magnitude of spillover in the model. Bouoiyour (2005) conducted a study on the Moroccan manufacturing industries, indicating that the channel of R&D spillover is through foreign direct investment, which has a significant positive effect on domestic labour productivity. He introduced the technology gap as a measure of absorptive capacity. It is calculated as the ratio between total factor productivity of foreign firms to the total factor productivity of domestic firms. This technology gap is a condition set in the model to have a higher positive magnitude effect of international R&D on domestic labour productivity.

The final conclusion of this literature survey, from which this chapter builds its basic assumptions, is that international R&D can be transmitted from industrial countries to developing countries through different mechanisms. It can significantly affect total factor productivity given the presence of high absorptive capacity. The main catalyst of this capacity is the quality of human capital, a narrow technology gap and innovation in information technology.

Methodology

In this section, we first present the empirical model used to estimate the effect of R&D spillover and human capital on labour productivity growth in the Egyptian manufacturing sector. We then discuss the methodology used to construct the international R&D spillover and capital stock.

Empirical Model

The empirical model depends on Cobb-Douglas production function. This model was developed by Corves (1997) and Gera et al. (1999):

$$Y_t = L_t^{\alpha_1} H_t^{\alpha_2} K_t^{\alpha_3} RD_t^{\alpha 4} e^{0t} \tag{9.1}$$

where α_1, α_2, $\alpha_{3,}$ and α_4 are the output elasticities of labour input, human capital, capital stock and international R&D capital respectively. α_4 represents the rate of exogenous technical change. All of the other variables are explained in Table 9.1.

From Eq. 9.1, we can derive the following equation that expresses the labour productivity growth rate of the manufacturing sector in Egypt.

Table 9.1 Sources and descriptions of data

Variable	Description	Expected sign	Source of data
Y	Labour productivity in manufacturing sector in Egypt. *Y* = GDP in manufacturing sector divided by employment	Dependent variable	Ministry of planning in Egypt, annual series
L	Employment level in manufacturing sector in Egypt	–	Ministry of planning in Egypt, annual series
H	Years of primary schooling	+	World Bank
K	Capital stock. It is calculated from the investment data by using the PIM technique explained in this section	+	Ministry of planning in Egypt, annual series
RD	International R&D, which is calculated from the R&D expenditure data by using the PIM technique explained in this section	+	STAN dataset, OECD

$$\left(\frac{\dot{y}}{y}\right) = \beta_0 + \beta_1\left(\frac{\dot{L}}{L}\right) + \beta_2\left(\frac{\dot{H}}{H}\right) + \beta_3\left(\frac{\dot{K}}{K}\right) + \beta_4\left(\frac{\dot{\mathrm{R}}\mathrm{D}}{RD}\right) + \in \tag{9.2}$$

Where $\left(\frac{\dot{y}}{y}\right)$ is the labour productivity growth; $\left(\frac{\dot{H}}{H}\right)$ is growth rate of the human capital; $\left(\frac{\dot{K}}{K}\right)$ is the growth rate of the capital stock; and $\left(\frac{\dot{R}D}{RD}\right)$ is the growth rate of the international R&D.

Measurement of R&D Spillovers

We calculated the international R&D as follows:

First, we calculated R&D expenditures for the G7 countries (USA, UK, Germany, France, Italy, Japan and Canada) by using the STAN dataset.

Second, we calculated the values of R&D at constant prices.

Third, we transferred these data from flows to stock by using the Perpetual Inventory Method (PIM)[1] by applying Eq. 9.3 for the benchmark year and Eq. 9.4 for the rest of the years (Elshamy 2009).

$$RD = \frac{RD \text{ flow in } 1982/83}{\text{Average annual growth rate} + \text{Depreciation rate}} \tag{9.3}$$

$$RD_i = RD_{i-1(1-\text{Depreciation rate})+RD \text{ flow in year } i} \tag{9.4}$$

Measurement of Capital Stock in Egypt

We calculated the international R&D as follows:

First, we collected the investment data for the manufacturing sector in Egypt during the period 1982/83–2010/11.

Second, we calculated the values of investments at constant prices.

Third, we transferred these data from flows to stock by using the Perpetual Inventory Method (PIM) by applying Eq. 9.5 for the benchmark year and Eq. 9.6 for the rest of the years.

$$K = \frac{\text{Investment flow in } 1982/83}{\text{Average annual growth rate} + \text{Depreciation rate}} \tag{9.5}$$

$$K_{i=}K_{i-1(1-\text{Depreciation rate})+\text{Investment flow in year } i} \tag{9.6}$$

Empirical Results

This section discusses the estimated results of Eq. 9.2. Regression was performed on a time series data consisting of 29 years (1982/83–2010/11) for the manufacturing sector in Egypt. First we conducted the cointegration analysis. Table 9.2 shows the results of the Augmented Dickey

[1] For more details about this method, see Elshamy (2009). Details of these findings can be interpreted as follows: in the Egyptian manufacturing sector, international R&D has a positive influence.

Table 9.2 Cointegration analysis

Dependent variable (growth of labour productivity)	Coefficients	Significant
Independent variables		
Constant	0.007	*
Growth of labour input	−0.411	***
Growth of human capital	0.012	**
Growth of capital input	0.019	*
International R&D spillover	0.056	***
CDRW	1.75	
ADF tests	Favoured lag length = 2	Favoured lag length = 2
ADF(0)	0.004	0.003
ADF(1)	0.052	0.022
ADF(2)	0.041	0.006
ADF(3)	0.031	0.004

*** = significant at 1 %
** = significant at 5 %
* = significant at 10 %
ADF figures show the Mackinnon approx P-value

Fuller (ADF) test on the first difference based upon the Mackinnon P values at various lag lengths. The preferred lag length based upon the Akaike Information Criterion (AIC) indicate that cointegration is generally accepted.

Table 9.2 shows the estimation results using cointegration analysis. We find that labour productivity has a positive and significant relationship with the growth rate of human capital, capital stock and international R&D. However, the relationship between labour productivity and the growth rate of employment is negative and significant. All of these results are correct according to the economic theory.

Details of these findings can be interpreted as follows: in the Egyptian manufacturing sector, international R&D has a positive influence on labour productivity, with a 1 % rise in international R&D increasing labour productivity by 5.6 %. Moreover, in the Egyptian manufacturing sector, human capital has a positive influence on labour productivity, with a 1 % rise in human capital increasing labour productivity by 1.2 %.

Table 9.3 shows the error correction mechanism (ECM). It indicates the same results as cointegration. Most importantly of course, the lagged

Table 9.3 Error correction mechanism (ECM)

Dependent variable (LFDI)	Coefficients	Significant
Independent variables		
Constant	0.006	*
Growth of labour input	−0.366	**
Growth of human capital	0.009	**
Growth of capital input	0.	*
International R&D spillover	0.048	**
Lagged error	−0.116	***
No. of observations	29	
F- statistics	8.33	***
Adjusted R^2	0.76	
DW	2.15	
AR(1)	1.42	
ARCH(1)	1.82	
Normality	2.12	

*** = significant at 1 %
** = significant at 5 %
* = significant at 10 %

error is negative and significant. This confirms the acceptance of the long-run relationship, which is further validated given that there are no problems with any of the diagnostic tests presented (the AR(1) test for first-order residual autocorrelation, the ARCH(1) test for autoregressive conditional heteroscedasticity and the Jarque-Beta test for normality).

Conclusions

This chapter empirically analyses the relationship between labour productivity, human capital and international R&D spillover during the period 1982–2011, by estimating a single model equation which employs long-run cointegration analysis and short-run analysis (ECM). The analysis uses annual data from 1982 to 2011.

Conventional results for international R&D and human capital are found. It is inferred from the model that significant role played by international R&D and human capital has strongly shaped labour productivity. These results are consistent with all literature surveyed in this research chapter, which supports the basic assumption that international research and development spillover is transmitted from industrial countries to developing countries like Egypt. In addition, this spillover affects labour productivity given the quality of human capital formation in Egypt.

The more developed the educational level of human capital in the industrial sector, the more significant its role will be in absorbing international research and development spillover and benefiting labour productivity.

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