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Abstract

The purpose of this paper is to introduce a suitable methodology for estimating the extent to which less developed countries—namely Tunisia—that hardly invest in research and development benefit from R&D that is conducted in industrial countries. In this study we use the imports of high-technology products as a proxy for the international spillovers measure and assess their impact on cost of production of the Tunisian manufacturing sector. Estimation results confirm the overall positive effect of trade as a channel of spillovers at the sectoral level. More precisely, imports of high-technology products and equipment enable recipient countries to benefit from foreign R&D. We demonstrated that foreign R&D spillovers decrease the demand for non-qualified labor and intermediate inputs, that physical capital and foreign R&D spillovers are complementary, and the interaction between capital formation and technological advances also applies to the international R&D spillovers effects.

JEL Classifications: O1, O3, C51.

Keywords: R&D, International spillover, adjustment costs, generalized McFadden functional form.

ملخص

الغرض من هذه الورقة هو تقديم منهجية مناسبة لتقدير مدى استفادة أقل البلدان نموا، وفى فى الورقة نسلط الضوء على تونس، التي بالكاد تستثمر من البحث والتطوير R & D والذى يجري في البلدان الصناعية. في هذه الدراسة نستخدم الواردات من منتجات التكنولوجيا المتقدمة كبديل لقياس الآثار الدولية غير المباشرة وتقييم أثرها على تكلفة الإنتاج في قطاع الصناعات التحويلية التونسية. تقدير نتائج تؤكد التأثير الإيجابي من إجمالي التجارة كقناة من الآثار الغير المباشرة على المستوى القطاعي. ولكى نكون أكثر دقة، فان الواردات من المنتجات والمعدات ذات التكنولوجيا العالية تمكن البلدان المتلقية للاستفادة من R & D. أثبتنا أن الآثار غير المباشرة R & D تقلل من الطلب على اليد العاملة غير المؤهلة والمدخلات الوسيطة، وأن رأس المال المادي الأجنبي اولآثار غير المباشرة R & D متكاملان، والتفاعل بين تكوين رأس المال والتقدم التكنولوجي ينطبق أيضا على R & D وآثار التداعيات الدولية.

1. Introduction

Despite the fact that R&D activity in the world economy is concentrated in industrial countries, R&D spillovers play a crucial role in modern economies. Since knowledge has some of the characteristics of a public good, the benefits of R&D stretch far beyond the limits of the original R&D performer (Griliches 1979; Spence 1984). These spillover effects are not necessarily contained within national boundaries. With the growing importance of international trade, foreign direct investment, and international knowledge diffusion (i.e. globalization of exchanges), a country's production structure and productivity growth depend not only on the accumulation of its own R&D capital, but also on the R&D activities conducted in others economies (Bernstein and Mohnen 1998). Recent theoretical arguments suggest that international spillovers of R&D are not confined to the industrial countries but are also important for less developed countries. More precisely, less developed countries like Tunisia, which are engaged in a liberalization process, may enjoy substantial benefits from R&D performed by their trade partners.

Structural adjustment efforts characterized Tunisia's economic development from 1987 onwards. In addition to standard fiscal and monetary policy reforms, Tunisia liberalized its financial sector. A policy of gradual trade liberalization was pursued, first by implementing current account convertibility, followed by accession to the GATT agreements, and then by a free trade association with the European Union in 1995, which went into effect on January 1, 2008. The agreement eliminates custom tariffs and other trade barriers on a wide range of goods and services. However, the most important aspect of the association agreement may well be that it has served to anchor Tunisia's commitment to reforms. To help Tunisian companies face foreign competition, public authorities put forward, in 1996, an industrial upgrading program, called Mise a Niveau. The goal of the program was to improve the competitiveness of the Tunisian industry, particularly on export markets. Launched on a pilot scale in 1996, the program, supported in part by EU grants, has consisted of technical assistance, training, subsidies, and infrastructure upgrades aimed at encouraging and assisting Tunisian private sector restructuring and modernization.

After twelve years, the results show that 3,860 enterprises were involved in the program (85% of the companies employed 20 persons or more), the investment represented €2,000 million and the grants: € 320 million of which 67% as material investment activities (supported by up to 12%) and 33% as immaterial investment activities (supported by up to 70%). The industrial exports increased four times between 1995 and 2007 and the high-technology exports increased from 2% of manufactured exports in 1995 to 4% in 2005. On the other hand, the imports of high-tech products represented around 40% of the total imports.

Economic literature on international spillovers considers international trade as an important channel in technological knowledge spillover. By trading with an industrial country that has a large stock of knowledge linked to its cumulative R&D activities, a developing country can boost its productivity by importing a larger variety of intermediate products and capital equipment embodying foreign knowledge [EU is Tunisia's largest trade partner (85% of total trade)].

The purpose of this paper is to introduce a suitable methodology for estimating the extent to which less developed countries—namely Tunisia—that hardly invest in research and development benefit from R&D that is performed in industrial countries. In this study we use the imports of high-technology products as a proxy for the international spillover measure in the technology space and assess their impact on cost of production of the Tunisian manufacturing sector.

The paper is organized as follows. Section II describes briefly the theoretical considerations of R&D spillovers. Section III presents the specification of the model and the method of estimation. Data sources and the measures of variables are described in section IV. The results and interpretations of estimates are presented in section V. In the last section, we conclude the paper.

2. Theoretical Considerations

International R&D spillovers can occur in a number of ways: trade in goods and services (Grossman and Helpman 1991; Coe and Helpman 1995), foreign direct investment (Blomström and Kokko 2003), highly skilled staff movements from multinational companies to domestic firms (Görg and Strobl 2005), international alliances between firms such as licensing agreements and joint ventures (Hagedoorn et al. 2000), international exchange of technologies through patents (Mohnen and Lépine 1988; Al-Azzawi 2004), international migration of scientists and engineers, international communication, such as conferences. Among all these ways, international R&D spillovers between developed and less developed countries can be observed mainly through trade or foreign direct investment. The others mechanisms mainly occur between developed countries. Thus, in this work, we focus our attention on the role of international trade as an important channel of R&D spillovers between countries (Tunisia and its trade partners).

The relationship between productivity growth, the stock of knowledge, international trade and spillovers can be examined either through the analysis of the effect on the growth rate of total factor productivity (Coe and Helpman 1995; Coe et al. 1997; Keller 2002; Crepso et al. 2002/2004; Lopez-Pueyo 2008) or by focusing on the impact on production cost and factors demand (Bernstein 1988/1989; Bernstein and Nadiri 1989; Rouvinen 2002). Studies on international R&D spillovers differentiate between domestic and foreign R&D spillovers and, in both cases, specify whether the technological externalities are inter-sectoral or intra-sectoral (Verspagen 1997; Braconier and Sjöholm 1998; Frantzen 2002; Keller 2002; Bitzer and Geishecker 2006). They also identify the channels of international trade as sources of R&D spillovers.

As summarized by Grossman and Helpman (1991), the theory of international trade and economic growth identifies four channels for R&D spillovers. First, international trade enables a country to use a larger variety of intermediate products and capital equipment, which helps to employ domestic resources more efficiently. Secondly, international trade releases learning process of production methods, product design, organizational methods and market conditions. Thirdly, international contacts enable a country to copy foreign technologies and adjust them to domestic use (i.e. imitation can be a source of performance as the case of Japan and the newly industrializing economies of East Asia). Finally, international trade can improve the productivity of a country in taking in foreign technologies. Thus, there are linkages between economic growth, domestic R&D capital and foreign R&D capital (Mc Neil and Fraumeni 2005). As noted by Coe et al. (1997), except for the first channel described above, all others may operate with equal force through foreign direct investment. While we plan to examine the role of foreign direct investment in future work, the empirical work presented here focuses on foreign trade as a channel of knowledge spillover. We should note that there is a lack of consensus throughout the literature from the empirical findings and techniques for the presence of spillover through trade (Keller 2004).

In order to benefit from international trade, a country needs to have trade partners that are capable of providing it with products, machines and equipment in which the country is in short supply. International spillovers depends thus on the trade partners' accumulated knowledge that is embodied in products, technologies and organizations. So, by trading with an industrial country that has a larger stock of knowledge, mainly by importing a larger variety of intermediate products and capital equipment embodying foreign knowledge, a developing country stands to improve its own stock of knowledge and enhance its productivity. Thus we construct a measure of the international R&D spillover as a weighted sum (by Tunisian imports) of the R&D stocks in five high-technology industries (non-electrical machinery; electrical products and electronic equipment; transportation equipment; chemical products; and scientific instruments) for Tunisia's main trade partners.

As noted by Bernstein and Nadiri (1991), there are a number of distinctive features of R&D spillovers. First, there are relationships between R&D capital and spillovers. The causality runs from R&D investment to R&D spillovers which, in turn, influence output supply and input demand decisions. Second, pecuniary and technological externalities associated with spillovers affect both product and demand. Product price, production cost, and demand level of one firm are affected by pecuniary and technological externalities associated with spillovers, i.e. by the R&D capital accumulation of others firms in the economy and outside the economy. Third, spillovers are intertemporal externalities. The existence of R&D spillovers implies that past R&D decisions of one firm can affect the current product price and production cost of others firms.

The R&D spillovers create a dichotomy between private and social rates of return to R&D capital because firms undertaking R&D investment are unable to exclude others from freely obtaining the benefits from R&D projects (Griliches 1979; Spence 1984). The benefits from R&D investment spill over to others firms in the economy and outside the economy, although the recipient firms have not paid for the use of knowledge generated by the R&D project. Because of the free-rider problem, firm's incentive to engage in R&D activities could be reduced. But, the literature suggests also that firms have to improve their absorptive capacity by investing in R&D to be able to use freely available knowledge (Cohen and Levinthal 1989). In others words, firms must have their own laboratories and staff of scientists and engineers in order to assimilate and use the knowledge obtained through spillovers. According to this argument, spillovers also provide an incentive for a firm to undertake its own R&D investment.

However, as noted by Coe et al. (1997), in most of the developing countries such as Tunisia, R&D investment is negligible. Data on the number of scientists and engineers or expenditure on reverse engineering that could be used to measure domestic stocks of knowledge is also limited. For these reasons, we assume that domestic R&D capital stock in Tunisia is very small and so can be ignored. However, we assume that productivity and absorptive capacity in a developing country like Tunisia depends on the quality of its labor force, i.e. on its human capital. The better the quality of human capital is, the more the country is taking better advantage of technological advances in its trade partners.

The theory also suggests that R&D spillovers play an important role in the explanation of productivity growth and productivity convergence across countries. By benefiting from foreign R&D knowledge, less developed countries grow faster and converge, even if slowly, to the productivity of the most advanced countries (Dollar and Wolf 1993; Coe and Helpman 1995; Coe et al. 1997; Bernstein and Mohnen 1998; Branstetter 2001; Funk 2001). A country's R&D investment reduces its cost of production and, through international R&D spillovers, also reduces the costs of production in others countries. As a consequence, and because of the dual role of R&D investment, spillovers affect both the cost of production through the productivity effect and the structure of production through the incentive or the R&D bias effect. Thus, the main purpose of this paper is to estimates the effects of R&D spillovers on the costs and structure of production of the receiving Tunisian industries. More precisely, the objective of this paper is therefore twofold. Firstly, we develop a measure to assess spillover effects, in Tunisia, of foreign R&D through the imports of high-tech product.

Secondly, as the unit cost is considered the main factor in determining the competitiveness of industries, we take into account the effect of foreign accumulated R&D knowledge in estimating the variable cost function of the Tunisian manufacturing industry. This is the first time that the consequences of foreign R&D spillovers have been estimated for the Tunisian manufacturing sector.

3. Model Specification

With these theoretical considerations in mind, our empirical work enables us to investigate the effects of R&D capital of Tunisia's trade partners on the costs and structure of production of Tunisian industries. In this model, firms choose the optimal levels of four inputs: capital K, materials M, and labor, which is divided into non-qualified labor L and qualified labor LQ. The production technology in Tunisian industry can be presented by a restricted variable cost function:

$$C_t^v = C^v(P_{Lt}, P_{Mt}, Y_t, LQ_{t-1}, K_{t-1}, S_{t-1}, T_t) \quad (1)$$

where C_t^v is the variable cost, t indexes time period and C^v is the variable cost function which is twice continuously differentiable, non decreasing in P_{Lt}, P_{Mt}, and Y_t, non increasing in K_{t-1} and LQ_{t-1}, concave and homogeneous of degree one in the two prices, and finally convex in K_{t-1} and LQ_{t-1}. Let's note that Y is the output, P_L is the price of non-qualified labor factor, P_M is the intermediate input price, K_{t-1} is the stock of physical capital at the period t-1, LQ_{t-1} is the stock of qualified labor at the period t-1 and T_t is the time trend that accounts for exogenous production efficiency gains and losses. As considered in several theoretical and empirical studies (Bernstein and Mohnen 1998; Hall et al. 2009), there is a one-year lag for the stocks of physical capital and qualified labor, as the end-of-period stocks of year t-1 enter the production function of year t.

S_t is the foreign R&D spillover which reduces the cost of production. The R&D spillover variable is constructed as a weighted sum (by Tunisian imports) of the R&D stocks in five high-technology industries. In this paper, we consider the main Europeans partners of Tunisia (Germany, Spain, France, Italy, Netherlands, United-Kingdom) and the United States.

$$S = \sum_i \sum_j \frac{M_{ij}}{\sum_i \sum_j M_{ij}} R_{ij}$$

where S is the spillover variable, M_{ij} denotes imports of Tunisia from sector i in country j and R_{ij} is the R&D stock of sector i in country j. The imports incorporating the foreign R&D are restricted to high-tech products.

Intermediate inputs and non-qualified labor are treated as flexible factors, while capital and qualified labor are treated as quasi-fixed factors. According to this specification, we can describe producers that use all available information to choose both flexible and quasi-fixed factor inputs over time so as to maximize the expected present discounted value of the flow of net revenue, given possible uncertainty over evolution of factor and output prices. I represents the part of investment subject to adjustment costs, and H is net hiring of qualified labor[1], that is,

$$I_t = K_t - (1-\delta_t)K_{t-1} \quad (2)$$

$$H_t = LQ_t - LQ_{t-1} \quad (3)$$

[1] We make adjustment costs a function of H for analytical convenience, and also because it is reasonable to expect that such costs are incurred when there are changes in overtime, etc. (see Pindyck and Rotemberg 1983).

where δ_t is the constant depreciation rate and measures the extent to which investment for replacement purposes incurs adjustment costs[2]. A higher depreciation rate of equipment requires more frequent capital replacement and generates disruption costs during installation of any new or replacement capital. This also generates costly learning as the structure of production must have been changed (Cooper and Haltiwanger 2006). We assume that changes in K and LQ result in costs of adjustment, represented by the convex functions $c_1(I_t)$ and $c_2(H_t)$ which will be defined below.

The technology is represented by the symmetric Generalized McFadden functional form introduced by Diewert and Wales (1987). Factor of production such as, energy, raw material and material are treated as variable inputs, i.e. immediately adjustable to their optimal level. However, the capital and qualified labor are modeled as quasi-fixed inputs subject to adjustment costs, such as the costs of reorganizing the production plan or breaking in new machines and the costs of giving up old techniques or introducing a new production line. Finally, the stock of foreign accumulated R&D knowledge is considered as a completely fixed input since we assume that Tunisian manufacturing sector is faced with an exogenously given level of it, over which it has no control.

We apply our model to the aggregate manufacturing sector treating it as competitive in factor markets, that is, firms take input prices as given. We can therefore view the sector as consisting of a single firm that has the technology of (1), or equivalently as consisting of many firms whose aggregate technology is represented by our model[3]. So, production decisions are determined under competitive conditions and according to the minimization of the expected discounted stream of costs. Factor demands are therefore given by the solution to the following equation (4)

$$\min_{K_\tau, LQ_\tau} E(t) \sum_{\tau=t}^{\infty} R_{t,\tau} \{C^v(P_{L\tau}, P_{M\tau}, Y_\tau, K_\tau, LQ_\tau, S_\tau, T) + \upsilon_\tau K_\tau + w_\tau^Q LQ_\tau + c_1(I_\tau) + c_2(H_\tau)\} \tag{4}$$

subject to equations (2) and (3). Here E denotes the conditional expectations operator in the current period, $R_{t,\tau}$is the discount rate between periods t and τ, υ_t is the real rental price of capital and w_t^Q is the real wage rate of qualified labor. The expectation in (4) is taken over all future values of P_L, P_M, υ, w^Q and Y, which are treated as random[4].

The minimization of (4) yields the following first-order conditions:

$$L_t = \frac{\partial C^v}{\partial P_{Lt}} \tag{5}$$

$$M_t = \frac{\partial C^v}{\partial P_{Mt}} \tag{6}$$

$$\frac{\partial C^v}{\partial K_t} + \vartheta_t + \frac{\partial c_1[K_t - (1-\delta_t)K_{t-1}]}{\partial K_t} + E(t)\left\{R_t \frac{\partial c_1[K_{t+1} - (1-\delta_t)K_t]}{\partial K_t}\right\} = 0 \tag{7}$$

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[2] Capital adjustment costs are a function of *gross* investment if δ is equal to the depreciation rate, and a function of *net* investment if δ is equal to zero. In general, δ can be anywhere between these values. Let's note that here we model adjustment costs as external to the firm. An alternative approach is to make adjustment costs internal by writing the cost function as $C^v(P_{L_t}, P_{Mt}, Y_t, LQ_{t-1}, K_{t-1}, S_{t-1}, I_t, H_t, T_t)$, but unless restrictions are placed on C a priori, this introduces too many parameters (see Pindyck and Rotemberg 1983).

[3] As noted by Pindyck and Rotemberg (1983), there are clearly potential aggregation problems here, as is often the case in work of this sort. The approach used here can be justified by the results of Lucas and Prescott (1971). They show that when competitive firms maximize profits, they act as if a central planner maximized aggregate welfare. This latter maximization requires the minimization of the discounted values of aggregate costs.

[4] But note that this does not mean that output Y must be viewed as "exogenous". The path of y depends on the realization of w, m, υ and w^Q as firms maximize profits (i.e. minimize costs).

$$\frac{\partial C^v}{\partial LQ_t} + w_t^Q + \frac{\partial c_2[LQ_t - LQ_{t-1}]}{\partial LQ_t} + E(t)\left\{R_t \frac{\partial c_2[LQ_{t+1} - LQ_t]}{\partial LQ_t}\right\} = 0 \qquad (8)$$

For notational simplicity, we have denoted the one-period discount factor $R_{t,t+1}$by R_t. Equations (5) and (6) are consequences of applying Shephard's Lemma (see Diewert 1982) and describe the demands for the variable factors. Equations (7) and (8) are the Euler equations, and describe the (expected) evolution of the quasi-fixed factors. For example, equation (7) says that the net effect on expected profits from the last unit of capital is just zero. That net effect consists of the variable cost savings $\partial C^v/\partial K_t$, a rental cost υ_t, a current adjustment cost $\partial c_1/\partial K_t$, and an expected (discounted) savings in future adjustment costs of $R_t \partial c_1[K_{t+1} - (1-\delta)K_t]/\partial K_t$. More generally, variable and quasi-fixed factor demands depend on the variable factor prices, output, capital inputs, net investment in the capital inputs, qualified labor, net hiring of qualified labor, time trend, and the R&D spillover. Finally, we note that equations (5)-(8) are in effect regression equations, and can be used to estimate the parameters of C, c_1 and c_2.

Consequently, we should specify the following functional form for the variable cost function which can be presented as a Generalized McFadden functional form. Thus,

$$C_t^v = Y_t^\rho \left\{\frac{1}{\tilde{P}_t}\left(\frac{1}{2}\alpha_{LL}P_{Lt}^2 + \alpha_{LM}P_{Lt}P_{Mt} + \frac{1}{2}\alpha_{MM}P_{Mt}^2\right) + \sum_{i=1}^2(\beta_{Ti}P_{it}T_t) + \tilde{P}_t\left(\frac{1}{2}\alpha_{KK}I_t^2 + \frac{1}{2}\alpha_{LQLQ}H_t^2\right)\right\} + \sum_{i=1}^2(\beta_{Ki}P_{it}K_{t-1}) + \sum_{i=1}^2(\beta_{LQi}P_{it}LQ_{t-1}) + \sum_{i=1}^2(\beta_{Si}P_{it}S_{t-1}) + \tilde{P}_t\left(\beta_{KT}K_{t-1}T_t + \beta_{LQT}LQ_{t-1}T_t + \beta_{ST}S_{t-1}T_t\right) + \tilde{P}_tY_t^{-\rho}\left(\frac{1}{2}\beta_{KK}K_{t-1}^2 + \beta_{KLQ}K_{t-1}LQ_{t-1} + \frac{1}{2}\beta_{LQLQ}LQ_{t-1}^2 + \beta_{KS}K_{t-1}S_{t-1} + \beta_{LQS}LQ_{t-1}S_{t-1}\right) \qquad (9)$$

where $i(1,2) = (L,M)$ and $\tilde{P} = \frac{P_{M0}M_0}{P_{M0}M_0 + P_{L0}L_0}P_M + \frac{P_{L0}L_0}{P_{M0}M_0 + P_{L0}L_0}P_L$ which is a weighted sum of variable factor prices (i.e. Laspeyres price index of the variable factors of production assessed at the base period). This variable appears in the variable cost function to stress the symmetric homogenous linearity in factor prices. Following Diewert and Wales (1987), the restriction $\alpha_{LL} = \alpha_{MM} = -\alpha_{LM}$ was imposed. As noted by Diewert and Wales (1988), this functional form is a semi-flexible one, i.e. a special case of a flexible form but which requires fewer free parameters to be estimated. In fact, the flexible functional form requires N(N+1)/2+2N+3 free parameters, i.e. 35 whereas here we estimate just 20 parameters.

The functional form considered is a simple extension of the one developed by Diewert and Wales (1987) by introducing the quasi-fixed factors. The main reason that leads us to prefer this form over the Translog or the Generalized Leontief is the possibility to impose parametrically the required curvature restrictions by a Cholesky factorization without further restricting the flexibility of the functional form. In others words, the attractiveness of this functional form is that the concavity and convexity properties of the variable cost function can be imposed without restricting the flexibility of the function.

As noted above, the normalized demand functions for variable factors are retrieved from the variable cost function by applying Shephard's Lemma:

$$\frac{L_t}{Y_t} = Y_t^{-\rho}\left\{\frac{1}{\tilde{P}_t}(\alpha_{LL}P_{Lt} + \alpha_{LM}P_{Mt}) - \tilde{L}\left(\frac{1}{2}\alpha_{LL}P_{Lt}^2 + \alpha_{LM}P_{Lt}P_{Mt} + \frac{1}{2}\alpha_{MM}P_{Mt}^2\right)\frac{1}{\tilde{P}_t^2} + \tilde{L}\left(\frac{1}{2}\alpha_{KK}I_t^2 + \frac{1}{2}\alpha_{LQLQ}H_t^2\right) + \beta_{LT}T_t\right\}$$
$$+ Y_t^{-1}(\beta_{LK}K_{t-1} + \beta_{LLQ}LQ_{t-1} + \beta_{LS}S_{t-1})$$
$$+ \tilde{L}\left\{Y_t^{-\rho-1}\left(\frac{1}{2}\beta_{KK}K_{t-1}^2 + \beta_{KLQ}K_{t-1}LQ_{t-1} + \frac{1}{2}\beta_{LQLQ}LQ_{t-1}^2 + \beta_{KS}K_{t-1}S_{t-1} + \beta_{LQS}LQ_{t-1}S_{t-1}\right) + Y_t^{-1}(\beta_{KT}K_{t-1}T_t + \beta_{RT}R_{t-1}T_t + \beta_{ST}S_{t-1}T_t)\right\} + \varepsilon_{1t} \quad (10)$$

$$\frac{M_t}{Y_t} = Y_t^{\rho-1}\left\{\frac{1}{\tilde{P}_t}(\alpha_{MM}P_{Mt} + \alpha_{LM}P_{Lt}) - \tilde{M}\left(\frac{1}{2}\alpha_{LL}P_{Lt}^2 + \alpha_{LM}P_{Lt}P_{Mt} + \frac{1}{2}\alpha_{MM}P_{Mt}^2\right)\frac{1}{\tilde{P}_t^2} + \tilde{M}\left(\frac{1}{2}\alpha_{KK}I_t^2 + \frac{1}{2}\alpha_{LQLQ}H_t^2\right) + \beta_{MT}T_t\right\} + Y_t^{-1}(\beta_{MK}K_{t-1} + \beta_{MLQ}LQ_{t-1} + \beta_{MS}S_{t-1})$$
$$+ \tilde{M}\left\{Y_t^{-\rho-1}\left(\frac{1}{2}\beta_{KK}K_{t-1}^2 + \beta_{KLQ}K_{t-1}LQ_{t-1} + \frac{1}{2}\beta_{LQLQ}LQ_{t-1}^2 + \beta_{KS}K_{t-1}S_{t-1} + \beta_{LQS}LQ_{t-1}S_{t-1}\right) + Y_t^{-1}(\beta_{KT}K_{t-1}T_t + \beta_{RT}R_{t-1}T_t + \beta_{ST}S_{t-1}T_t)\right\} + \varepsilon_{2t} \quad (11)$$

where $\tilde{L} = \frac{P_{L0}L_0}{P_{M0}M_0 + P_{L0}L_0}$ and $\tilde{M} = \frac{P_{M0}M_0}{P_{M0}M_0 + P_{L0}L_0}$ measured at the base period. Equations (10) and (11) are normalized by Y_t to avoid an eventual heteroscedastcity problem in random error terms. The stochastic error terms represent non-observable technological shocks and reflect eventual errors of optimization.

The expected values associated to Euler equations are replaced with future values realized, the difference between them being the error term not correlated with the available information at period *t*.

Following Pindyck and Rotemberg (1983), we make the adjustment cost functions quadratic, that is,

$$c_1(I_t) = \lambda_1 I_t^2/2 \quad (12)$$

$$c_2(H_t) = \lambda_2 H_t^2/2 \quad (13)$$

Then, equations (7) and (8) become:

$$C_{Kt} + \vartheta_t + \lambda_1[K_t - (1-\delta_t)K_{t-1}] - E(t)\{R_t(1-\delta_t)\lambda_1[K_{t+1} - (1-\delta_t)K_t]\} = 0 \quad (14)$$

$$C_{LQt} + w_t^Q + \lambda_2[LQ_t - LQ_{t-1}] - E(t)\{R_t\lambda_2[LQ_{t+1} - LQ_t]\} = 0 \quad (15)$$

where C_{Kt} and C_{LQt} are defined as: $C_{Kt} = \frac{\partial C^v}{\partial K_t}$ and $C_{LQt} = \frac{\partial C^v}{\partial LQ_t}$

The set of equations to be estimated consists of (10), (11), (14) and (15). These equations relate to the demand for the factors of production. Our emphasis in this paper is on the effects that international R&D spillovers exert on production structure and costs of production of the manufacturing sector in Tunisia.

4. Data

Five high-technology industries were analyzed in this paper: chemical products; non-electrical machinery; electrical machinery; transportation equipment; and scientific instruments. The sample period is 1977-2009. Most of the data for these industries was obtained from published sources of the OECD and from the databases of Tunisian statistical institutions[5]. For each industry, the output (Y) is measured by the costs of factors. There are two variable factors, intermediate input (materials) and non-qualified labor. Real materials were defined as gross output minus real value-added. The materials price (P_M) was implicitly calculated as the ratio of nominal materials to real materials. Non-qualified labor (L) is the total number of foremen, machine operators, manual workers and trainees. The wage rate (P_L) is the total compensation for non-qualified labor in each industry.

There are two quasi-fixed factors, physical capital and qualified labor which is a proxy to assess the absorptive capacity of an industry. Physical capital (K) is defined as the sum of structures and equipment capital stocks. Assuming that interest payments are fully deductible, as they are in Tunisia, and following the World Bank method[6], the rental rate of physical capital is defined as: $\upsilon = q(r(1-t)+d)$ where q is the physical capital deflator (i.e. the detailed system of fiscal and financial incentives has not been considered), r is the real lending interest rate[7], t is the corporate tax rate[8], and d is the depreciation rate[9]. Qualified labor (LQ) is measured by the number of technicians and engineers/administrators. The qualified labor variable is intended to reflect the sector's technological capabilities and is used as a proxy for the absorptive capabilities of the Tunisian manufacturing sector. The wage rate (w^Q) is the total compensation for qualified labor in each industry.

In the empirical literature various ways have been adopted to measure R&D spillovers. The pool of R&D spillovers has been defined as the sum of R&D expenditures (see Griliches 1998; Evenson and Kislev 1973; Levin and Reiss 1984//1988), the sum of R&D capital stocks (Bernstein 1988; Bernstein and Nadiri 1989; Coe and Helpman 1995) and the patent weighted sum of R&D expenditures (Scherer 1982/1984; Griliches and Lichtenberg 1984; Jaffe 1986; Mohnen and Lepine 1991). In all these studies the pool of R&D was defined as a single variable. However, as developed by recent studies (McNeil and Fraumenti 2005; Bitzer and Geishecker 2006), we consider the foreign R&D capital stock weighted by manufacturing imports. More precisely, we assess the role of imports of high-technology products as the main trade channel of spillover. It enables manufacturing to better benefit from foreign knowledge embodied in products. The spillover variable represents intra-industry and international R&D spillover between Tunisia and its trade partners. More precisely, it shows how Tunisian manufacturing can benefit from foreign knowledge by importing and using foreign products.

The R&D spillover variable $S = \sum_i \sum_j \frac{M_{ij}}{\sum_i \sum_j M_{ij}} R_{ij}$ is constructed as a weighted sum (by Tunisian imports) of the R&D stocks in the five high-technology industries considered here. In this paper, we consider the main trade partners of Tunisia (United States, Germany, Spain, France, Italy, Netherlands and United Kingdom). M_{ij} denotes Tunisian imports in sector i from country j (excluding imports flowing to final demand) and R_{ij} denotes R&D stock of

[5] These institutions are: National Institute of Statistics (INS) and Institute of Quantitative Economy (IEQ) in Tunisia and OECD: Science, Technology and R&D statistics Database.

[6] World Bank, August 1995, Report No. 13993-TUN,Volum II Annexes, Republic of Tunisia - Poverty Alleviation: Preserving Progress while Preparing for the Future.

[7] The lending rate used is the money market rate plus 3 percentage points, the different preferential sectoral interest rates were not taken into consideration.

[8] To simplify the calculation, a 50% tax rate is applied for 1983-88, and with the tax reform in 1989, the normal corporate tax of 35% is applied for 1989-2004. No differentiation between the wholly exporting and agricultural enterprises is considered, and various tax holidays have not been applied.

[9] The average depreciation rate is of 2.9% for building and 6.7% for equipment, thus a weighted average rate has been calculated and a uniform value of 5.5% was assumed.

sector *i* in country *j*. The share of intermediate consumption in goods was about 65% which is the average value across the period considered[10]. The imports incorporating the foreign R&D are restricted to high-technology products between 1980 and 2005. The list of such products is based on the OECD list[11] and the R&D data is borrowed from the ANBERD of the OECD database on R&D[12]. Foreign R&D capital is defined as the accumulation of deflated R&D expenditures. For each country and sector, initial deflated expenditures are grossed up by the average annual growth rate of physical capital in order to obtain initial R&D capital stock. Given the initial stock, foreign R&D capital is calculated according to the perpetual inventory formula using the R&D capital depreciation rate which was assumed to be 10% (see Hall (2007) for a review of the implications of this assumption on the returns to R&D).

5. Estimation Results

The equation set [i.e. (10), (11), (14) and (15)] are jointly estimated using the Generalized Method of Moments (GMM) estimators developed by Hansen (1982).

The estimates of our model are based on the following set of instrumental variables which are supposed to be known at time t and are uncorrelated with the error terms of our estimating equations. We choose a constant term, the capital stock and the output lagged two periods as well as the relative variable factor prices and the R&D stock lagged one period. The concavity and convexity conditions are imposed by the Wiley. Schmidt and Bramble technique also called the Cholesky decomposition (Diewert and Wales 1987). The results of our search for a global minimum of the objective function are presented in table 1. β_{KK} , β_{KLQ} and β_{LQLQ} were set equal to zero. We also had difficulties to achieve convergence when estimating α_{LL} and constraining it to be positive. We therefore imposed α_{LL} to be zero as well.

Quite a number of coefficients are insignificant, particularly the technological change parameters. However the foreign R&D spillover decreases the demand for the non-qualified labor and intermediate inputs (β_{LS} and β_{MS}) . The second interesting result is that capital and foreign R&D spillover are complementary (β_{KS}). This result suggests that the interaction between capital formation and technological advance also applies to the international R&D spillover effects.

The returns to scale are obtained from the following formula (Caves, Christensen and Swanson 1981):

$$\eta_t = (\mathbf{1} - \partial \ln VC_t / \partial \ln K_{t-\mathbf{1}} - \partial \ln VC_t / \partial \ln LQ_{t-\mathbf{1}} - \partial \ln VC_t / \partial \ln S_{t-\mathbf{1}}) / (\partial \ln VC_t / \partial \ln Q_t) \quad (16)$$

According to this measure, returns to scale are measured as the elasticity of the growth of output with respect to an equiproportional growth of all the inputs, including qualified labor and R&D spillovers.

The Tunisian manufacturing sector displays returns to scale of the order of 1.26. That means that when output increases by 10%, average cost decreases by about 20%.

The adjustment costs do not appear to be very large. For example every dinar of capital expenditure costs almost 1.004 when adjustment costs are included and 1.010 for the qualified labor.

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[10] This share calculated from the input-output table represents the average value of shares related to the years 1983, 1987, 1991, 1995, 1999 and 2004 according to the formula *CI/P-X+IM*, where *CI* is the intermediate consumption, *P* the output, *X* the exports and *IM* the imports.

[11] O.E.C.D (2007), *Science, Technology and Industry Scoreboard*, O.E.C.D, Paris.

[12] O.E.C.D. *Analytical Business Enterprise Research and Development* database (ANBERD).

The immediate rates of return for capital, foreign R&D spillover and qualified labor are computed as their short-run shadow prices divided by their effective purchase prices. The rate of return on foreign R&D is higher than the corresponding return on capital. The negative rates of return on qualified labor suggest that there was no room for a wage markup for higher qualifications.

Finally we estimate that the rate of disembodied technical change was on average 1.2% during the sample period. The fact that β_{KT} and β_{ST} are negative indicates that technical change reinforces the cost decreasing effects of capital and foreign R&D.

6. Conclusion

Recent theoretical models of international trade and economic growth highlight the importance of trade as a vehicle for technological spillovers. There have been many empirical cross-country studies which concerns developed countries. For the most part, however, these studies do not assign an important role to innovative activity in, or trade with, the industrial countries in explaining the effect on productivity and cost of production in the less developed countries. Spillovers allow less developed countries to close the technological gap *vis-à-vis* the industrial countries. However, our paper has presented empirical evidence that cost of production, industrial structure and factor demand in developing countries are closely related to R&D in their industrial trade partners and, more precisely, to their imports of products, machinery and equipment in high-technology industries from industrial countries.

Estimation results confirm the overall positive effect of trade as a channel of spillovers at the sectoral level. More precisely, imports of high-technology products and equipment enable recipient countries to benefit from foreign R&D. We demonstrated that the foreign R&D spillover decreases the demand for non-qualified labor and intermediate inputs, that capital and foreign R&D spillover are complementary and the interaction between capital formation and technological advances also applies to the international R&D spillover effects.

They also suggests that we have to do research in order to know what is going on in the field of science and technology and to be able to assimilate what is there available to us.

There are a number of further areas of research with respect to R&D spillovers. First, foreign direct investment could be an important channel of R&D spillovers. We can find evidence of significant knowledge spillovers from foreign affiliates to domestic firms if the latter have a significant absorptive capacity. Further, we can analyze different forms of knowledge diffusion. Licensing agreements, joint ventures and imitation are different channels through which diffusion occurs, and each could generate distinct spillovers with their own effects on cost reduction. Second, in order to better benefit from foreign knowledge, public authorities should not only be satisfied with increasing domestic R&D expenditures without paying any attention to the broad institutional context in which innovation and technological development take place. Finally, it seems important to distinguish between inter-industries and intra-industry spillovers and also between upstream and downstream industries in order to better analyze the sources of spillovers.

References

Al-Azzawi, S. 2004. Foreign direct investment and knowledge flows: Evidence from patent citations. University of California, Davis, Department of Economics.

Bernstein, J.I. 1988. Costs of production, intra and inter industry R&D spillovers: Canadian evidence. *The Canadian Journal of Economics* 21(2): 324–47.

Bernstein, J.I. 1989. The structure of Canadian inter-industry R&D spillovers, and the rates of return to R&D. *The Journal of Industrial Economics* 3, 315–28.

Bernstein, J.I., and P. Mohnen. 1998. International R&D spillovers between U.S. and Japanese R&D intensive sectors. *Journal of International Economics* 44, 315–338.

Bernstein, J.I., and I. Nadiri. 1989. Research and development and intra-industry spillovers: An empirical application of dynamic duality. *Review of Economic Studies* 56, 249–269.

Bernstein, J.I., and I. Nadiri. 1991. Product Demand, Cost of Production, Spillovers, and the Social Rate of Return to R&D. NBER Working Paper 3625.

Bitzer, J., and I. Geishecker. 2006. What drives trade-related R&D Spillovers? Decomposing knowledge-diffusing trade flows. *Economics Letters* 93, 52–57.

Blomström, M., and A. Kokko. 2003. The economics of foreign direct investment incentives. NBER Working Paper 9489.

Braconier, H., and F. Sjöholm. 1998. National and international spillovers from R&D: comparing a neoclassical and an endogenous growth approach. *Weltwirtschaftliches Archiv* 134, 639–63.

Branstetter, L. 2001. Are knowledge spillovers international or international in scope? Microeconomic evidence from the U.S. and Japan. *Journal of International Economics* 53: 53-79

Caves, D.W, L.R. Christensen and J.A. Swanson. 1981; Productivity Growth, Scale Economies and Capacity Utilization in U.S Railroads, 1955-74. *American Economic Review* 7: 993-1002

Choi, J., and K. Abderrahim. 2012. Country specific context: Review of existing policies and identification of constraints. In *Comparative study on export policies in Egypt, Morocco, Tunisia and South Korea,* ed. AFD. African Development Bank Report.

Coe, D.T., E. Helpman and A. W. Hoffmaister. 1997. North-South R&D spillovers. *The Economic Journal* 107, 134–49.

Coe, D.T., and E. Helpman. 1995. International R&D spillovers. *European Economic Review* 39, 859–87.

Cohen, W.M., and D.A. Levinthal. 1989. Innovation and learning: The two faces of R&D. *The Economic Journal* 99(3): 569–96.

Cooper, R.W., and J.C. Haltiwanger. 2006. On the nature of capital adjustment costs. *Review of Economic Studies* 73 (3): 611-633.

Crepso, J., C. Martin, and F.L. Velazquez. 2002. International technology diffusion through imports and its impact on economic growth. European Economy Group. Working Paper 12/2002. Universidad Complutense, Madrid.,

Crepso, J., C. Martin, and F.L. Velazquez. 2004. The role of international technology spillovers in the economic growth of the OECD countries. *Global Economy Journal* 4(2): 1–18.

Diewert, W.E. 1982. Duality approaches to microeconomic theory. In *Handbook of mathematical economics* 2nd edition, ed. K. Arrow and M. Intrilligator. Amsterdam, The Netherlands: Elsevier Science Publishers.

Diewert, W.E., and T.J. Wales. 1987. Flexible functional forms and global curvature conditions. *Econometrica* 55, 43–68.

Diewert, W.E., and T.J. Wales. 1988. A Normalized Quadratic Semiflexible Functional Form. Journal of Econometrics 37, 327–342.

Dollar, D., and E. Wolf. 1993. *Competitiveness, convergence, and international specialization*. Cambridge: MIT Press.

Evenson, R.E. and Y. Kislev. 1973. Research and productivity in wheat and maize. *Journal of Political Economy*. 81(6). 1309-1329

Frantzen, D. 2002. Cross-sector and cross-country technical knowledge spillovers and the evolution of manufacturing productivity: A panel data analysis. *Economie Appliquée* LV, 31–62.

Funk, M.F. 2001. International R&D spillovers and convergence among OECD countries. *Journal of Economic Integration* 16(1): 48–65.

Görg, H., and E. Strobl. 2005. Spillovers from foreign firms through worker mobility: An empirical investigation. *Scandinavian Journal of Economics* 107, 693–709.

Griliches, Z. 1979. Issues in assessing the contribution of research and development to productivity growth. *Bell Journal of Economics* 10, 92–116.

Griliches, Z. (Ed). 1984. *R&D, Patents and Productivity*. University of Chicago Press. Chicago.

Griliches, Z. 1998. The Search for R&D Spillovers, in Zvi Griliches, ed., *R&D and Productivity: The Econometric Evidence*, University of Chicago Press, Chicago.

Griliches, Z. and F. Lichtenberg. 1984. Interindustry technology flows and productivity growth: a reexamination. *Review of Economics and Statistics.* 66: 324-329

Grossman, G.M., and E. Helpman. 1991. Trade, knowledge spillovers, and growth. NBER Working Paper 3485.

Hagedoorn, J., A.N. Link, and N.S. Vonortas. 2000. Research partnerships. *Research Policy* 29(4–5): 567–86.

Hall, B.H. 2007. Measuring the returns to R&D: The depreciation problem. NBER Working Paper 13473.

Hall, B.H., J. Mairesse, and P. Mohnen. 2009. Measuring the returns to R&D. NBER Working Paper 15622.

Hansen, L.P. 1982. Large sample properties of generalized method of moments estimators. *Econometrica* 50(4): 1029–53.

Jaffe, A. B. 1986. Technological Opportunity and Spillovers of R&D: Evidence from Firms'Patents, Profits, and Market Value, *American Economic Review* 76: 984-1001.

Keller, W. 2002. Geographic localization of international technology diffusion. *American Economic Review* 92(1): 120–42.

Keller, W. 2004. International technology diffusion. *Journal of Economic Literature* 32(3): 752–82.

Kenawy, E.M. 2009. The economic development in Egypt during the 1952–2007 period. *Australian Journal of Basic and Applied Sciences* 3(2): 588–603.

Levin, R.C. and P.C. Reiss. 1984. Tests of a Schumpeterian model of R&D and market structure. In Z. Griliches, ed., R&D, Patents and Productivity. University of Chicago Press.

Levin, R.S. and P.C. Reiss. 1988, Cost-Reducing and Demand-Creating R&D with Spillovers. *The Rand Journal of Economics*. 19(4). 538-556

Lopez–Pueyo, C., S. Barcenilla–Visus, and J. Sanau. 2008. International R&D Spillovers and manufacturing productivity: A panel data analysis. *Structural Change and Economic Dynamics* 19, 152–72.

Lucas, Robert E. and Edward C. Prescott. 1971. Investment Under Uncertainty. *Econometrica* 39(5): 659-681.

McNeil, L.R. and B.M. Fraumeni .2005. International Trade and Economic Growth: A Possible Methodology for Estimating Cross-Border R&D Spillovers. Bureau of Economic Analysis. Working Paper 2005-03. Washington, D.C.

Mohnen, P., and N. Lépine. 1991. R&D, R&D spillovers and payments for technology: Canadian evidence. *Structural Change and Economic Dynamics* 2(1): 213–29.

O.E.C.D. 2007. *Science, Technology and Industry Scoreboard*, O.E.C.D, Paris.

O.E.C.D. *Analytical Business Enterprise Research and Development* database (ANBERD). OECD. Science, Technology and R&D statistics Database

Pindyck, R.S., and J.J. Rotemberg. 1983. Dynamic factor demands and the effects of energy price shocks. *American Economic Review* 73(5): 1066–79.

Rouvinen, P. 2002. The existence of R&D spillovers: A cost function estimation with random coefficients. *Economics of Innovation and New Technology* 11(6): 525–41.

Scherer, F.M. 1982. Inter-industry technology flows and productivity growth. *Review of Economics and Statistics.* 64: 627-637

Scherer, F. M. 1984. Using Linked Patent and R&D Data To Measure Inter-Industry Technology Flows, in Zvi Griliches, ed., *R&D, Patents, and Productivity*. University of Chicago Press.

Spence, A.M. 1984. Cost reduction, competition and industrial performance. *Econometrica* 52: 101–21.

Verspagen, B. 1997. Measuring inter-sectoral technology spillovers: Estimates from the European and US patent office database. *Economic Systems Research* 9: 49–67.

Table 1: GMM Estimates of the Tunisian Manufacturing Sector, 1978-2003

Parameters	Estimates	t-Statistics
ρ	0.791	6.641
α_{LL}	-	-
α_{LQLQ}	-0.007	-0.324243E-06
α_{KK}	-0.102	-0.016
β_{LK}	-0.038	-2.847
β_{LLQ}	0.112	1.085
β_{LS}	0.035	13.194
β_{LT}	0.007	0.277
β_{KK}	-	-
β_{KLQ}	-	-
β_{KT}	-0.049	-1.373
β_{KS}	-0.197	-2.748
β_{LQT}	0.057	0.648
β_{LQS}	0.294	0.544
β_{LQLQ}	-	-
β_{ST}	-0.275	-1.169
β_{MK}	0.565	2.772
β_{MLQ}	-0.859	-0.610
β_{MS}	0.231	8.662
β_{MT}	0.717	1.376
J-Statistics	47.097	
Durbin-Watson statistic	Equ (10): 0.72	Equ (14): 2.30
	Equ (11): 0.23	Equ (15): 1.01

Table 2: Rates of Return, Adjustment Costs and Return to Scale (Sample Averages)

Returns to scale	1.26
Marginal adjustment costs of capital / effective price of capital	0.004
Marginal adjustment costs of qualified labor / effective price of qualified labor	0.010
Gross rate of return on capital (shadow price/effective purchase price):	10.90%
Gross rate of return on qualified labor (shadow price/effective price)	-2.40%
Gross rate of return on foreign R&D (shadow price/Tunisian GDP Deflator):	20.70%
Rate of disembodied technical change	1.20%