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The impact of R&D and knowledge diffusion on the productivity of manufacturing firms in Turkey

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Abstract As the experiences of newly industrialized economies have shown, R&D and knowledge diffusion can play a crucial role in spurring the innovation capacity and productivity of emerging economies. Using firm level manufacturing data from 2003 to 2007, this paper investigates whether R&D intensity and various channels of knowledge diffusion affect productivity in Turkey—one of the fastest-growing emerging economies of the past decade. We find that an increase in the foreign ownership share in firms and technology licensing increases firms' productivity—although the conditional effect of the latter is significant only above a threshold of technological capability. Moreover, an increase in R&D intensity raises productivity only in firms with a threshold of technological capability, while industry level R&D spillovers do so only in firms with above average technological capability. These results support the view that emerging economies such as Turkey would benefit greatly from investing in technological capacity building, technology licensing as well as from attracting greater foreign direct investment.

Keywords R&D · Knowledge diffusion · Productivity · Emerging economies · GMM · Interaction models

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1 Introduction

Although the research and development (R&D), knowledge diffusion and productivity linkages have not been explored at length in the context of developing countries, there is compelling evidence that both international knowledge diffusion channels and R&D have played a critical role in the promotion of productivity in newly industrialized and emerging economies of East and Southeast Asia (i.e., Hobday 1995; Liao et al. 2009; Ang and Madsen 2011; Heshmati and Kim 2011; Yasar 2013).[1] Existing studies on the emerging economies of other regions show that while international knowledge spillovers promote productivity in these economies, there is only weak evidence for the impact of their R&D investment on productivity (i.e., Raut 1995; Shiff and Wang 2006; Goedhuys 2007; Banda and Verdugo 2011; Crespi and Zuniga 2012).

Building on endogenous growth theories and existing empirical literature on emerging market economies, this paper investigates the impact of in-house R&D stock and various channels of knowledge diffusion on the productivity of manufacturing firms in Turkey using nationally representative firm level panel data from 2003 to 2007. Turkey's notable economic performance since the 2001 financial crisis, together with its increasing efforts in

[1] Newly industrialized economies of these regions are Hong Kong SAR, China; the Republic of Korea; Singapore and Taiwan, China. Emerging economies are China, Indonesia, Malaysia, and Vietnam.

technology adoption and global economic integration, makes it an interesting case study to understand the relationship between knowledge diffusion, R&D and productivity in emerging economies.

The main contributions of this study are: (a) it is the first to examine the impact of R&D and several knowledge diffusion channels on the productivity of manufacturing firms in Turkey, (b) using the interaction model, it explores the effect of firms' technological capability on their ability to use R&D and knowledge diffusion channels effectively to increase their productivity and (c) it uses the most comprehensive database in Turkey collected by the Turkish Statistics Office from nationally representative manufacturing firms and employs the system generalized method of moment (GMM) analysis to account for potential endogeneity issues.

Our findings show that average impact of foreign ownership share in firms and technology licensing on the productivity of firms is positive and significant, while the conditional impact of technology licensing depends on a threshold of technological capability of firms. An increase in in-house R&D intensity promotes productivity only in firms with a threshold of technological capability, while increases in R&D spillovers from foreign firms and industry level R&D spillovers promote productivity only in firms with high technological capability. Among the firms with lowest technological capability, the impact of the former three indicators mentioned above on productivity is insignificant, but overall industry level R&D spillovers actually have a negative impact. Meanwhile, there is no evidence that changes in firms' international trade significantly affect their productivity.

The remainder of the paper is structured as follows: The subsequent section provides a brief overview of the recent trends of relevant economic indicators in Turkey. Section 3 reviews the theoretical and empirical work, and Sect. 4 describes the data and reports the findings of simple statistical analyses across different groups of firms and sectors. Section 5 describes the model, Sect. 6 analyzes the findings of the econometric analysis and Sect. 7 concludes the paper.

2 Trends in output, R&D and knowledge diffusion channels in Turkey

Turkey has made considerable efforts to foster its gross domestic product (GDP) growth as well as its R&D, manufacturing value added and international knowledge diffusion channels during the past decade. As seen in Figs. 1 and 2, throughout 2003–2007, GDP recorded the highest average growth, and both per capita GDP and per worker manufacturing value added have increased consistently. Although Turkey's R&D share of GDP is still far below the emerging market average and that of China and Brazil, it has been on an upward trend since mid-2000s, averaging 0.58 % of GDP during 2003–2007 and reaching 0.85 % in 2009–2010, surpassing India (Fig. 3). Turkey has also increased its business R&D share of GDP from 0.14 % in 1996–2002 to 0.19 % in 2003–2007 and to 0.35 % in 2009–2010 (OECD 2011).

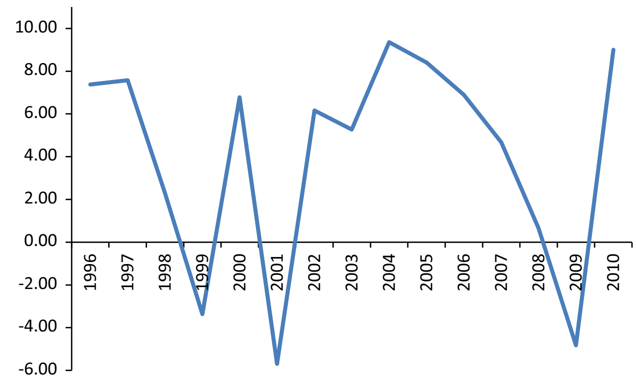

Fig. 1 Growth rate of Turkey's real GDP (%). *Source*: WDI database, World Bank Group

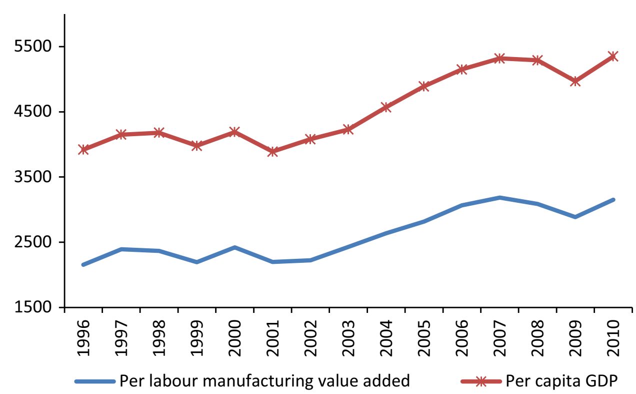

Fig. 2 Turkey's per capita GDP and per labor manufacturing value added (constant 2000 US$). *Source*: WDI database, World Bank Group

In terms of international knowledge diffusion channels, Turkey has had a consistently high trade share of GDP since its liberal economic policies of the 1980s. As Fig. 4 shows, Turkey's average trade share of GDP has been around 48 % throughout the 1990s and 2000s, outpacing that of many other emerging economies and OECD high-income economies. Although it had very low levels of foreign direct investment (FDI) throughout the 1980s and 1990s, Turkey has managed to increase its FDI inflows substantially since 2000, averaging a striking 2.5 % of GDP during the late 2000s, leaving behind India, Argentina, Brazil and Mexico (Fig. 5). However, technology licensing in Turkey remains very low at 0.10 % (Fig. 6),

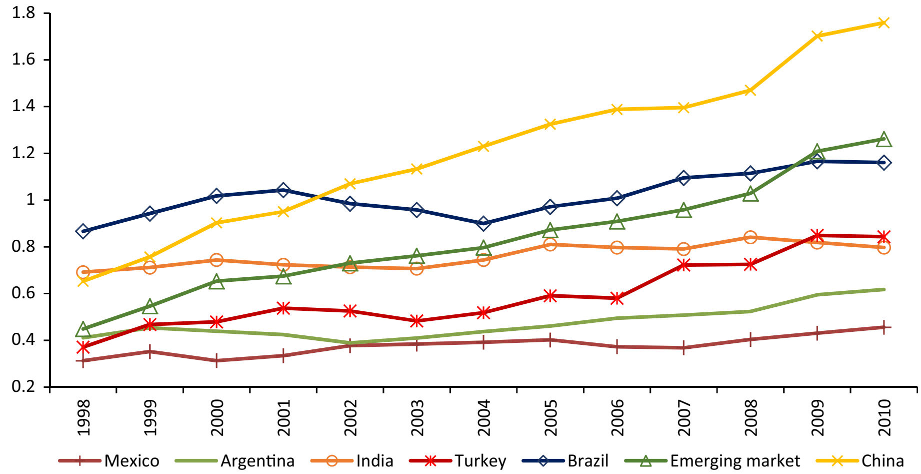

Fig. 3 R&D expenditure/GDP (%). *Source*: WDI database, World Bank Group

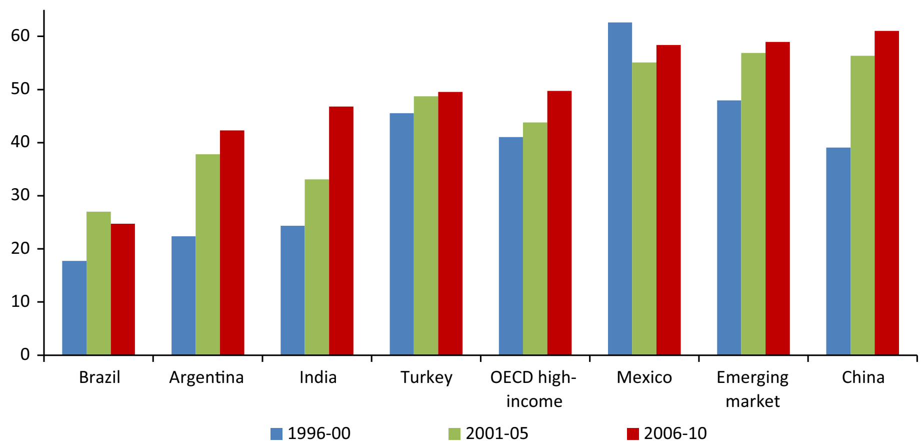

Fig. 4 Trade/GDP (%). *Source*: WDI database, World Bank Group

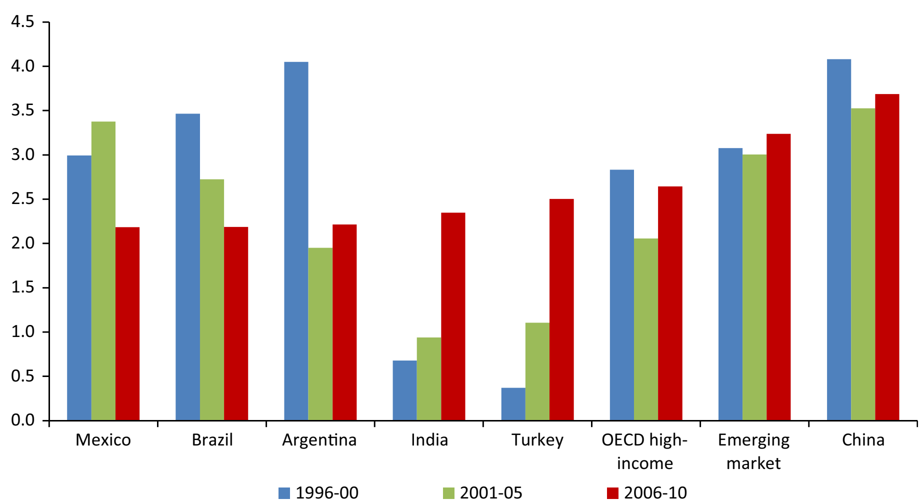

Fig. 5 Net FDI inflows/GDP (%). *Source*: WDI database, World Bank Group

which is alarming as technology licensing provides direct access to new technology and thus has more potential for transferring new knowledge to local firms than other channels such as international trade, FDI and R&D efforts of neighboring firms.

3 Theoretical and empirical literature

The groundbreaking first-generation endogenous growth theories of Romer (1990), Grossman and Helpman (1991) and Aghion and Howitt (1992) incorporated R&D,

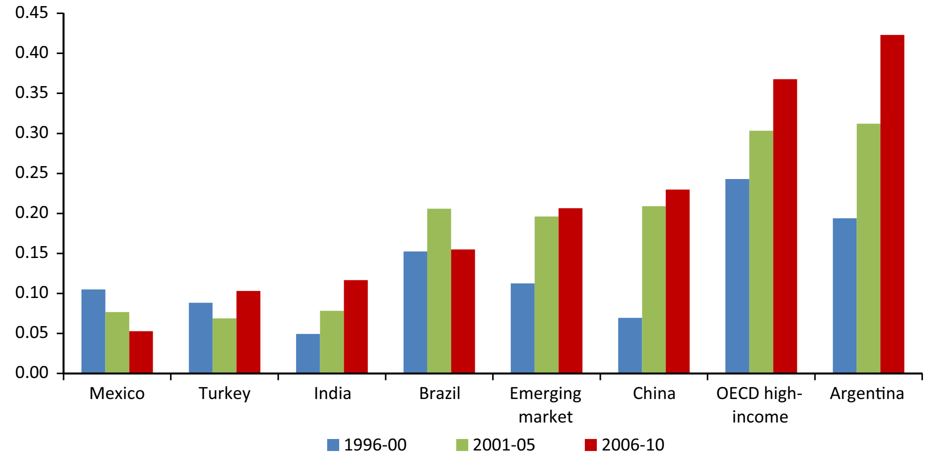

Fig. 6 Royalty and license fee payments/GDP (%). *Source*: WDI database, World Bank Group

knowledge diffusion and monopolistic competition into the theories of economic growth, producing testable hypotheses and paving the way for empirical exploration of the determinants of technological innovation and long-term growth. The subsequent second-generation endogenous growth theories led by Aghion and Howitt (1998), Young (1998) and Dinopoulos and Thompson (2000) removed the empirically void *scale effect* prediction of the earlier models, making them more applicable to world economies and prompting a large body of empirical work in growth literature (i.e. Zachariadis 2003; Ulku 2007). The main premises of all endogenous growth theories are that long-term productivity and growth rate of output are driven by innovation, which are determined by R&D efforts of firms and knowledge diffusion.

Other prominent theoretical studies also examined the impact of various knowledge diffusion channels—such as trade, FDI, R&D spillovers and technology licensing—on the productivity and growth rates of developing countries and pointed out a positive relationship between these variables (i.e., Wang 1990; Wang and Blomstrom 1992; Borensztein et al. 1998; Eaton and Kortum 2001; Glass and Saggi 2002). However, as first put forward by Gerschenkron (1962) and investigated further by subsequent studies such as Kim (1980), Cohen and Levinthal (1990), Lall (1992), Madsen et al. (2010), Fu et al. (2011) and Yasar (2013), effectiveness of knowledge diffusion in promoting productivity and growth largely depends on the level of countries' *absorptive capacity* and *technological capability*. This means that those countries with higher levels of human capital and R&D capacity process and utilize new information and technology faster than others.

Among the knowledge transmission mechanisms mentioned above, technology licensing provides potentially the most rapid and direct access to advanced technology, as it gives the licensees the right to use the blueprint of new technology in their production. Firms licensing technology are shown to learn, adopt and assimilate new technology and increase their innovative capacity more successfully than other firms (Danneels 2002; Leone et al. 2010; Banda and Verdugo 2011).

FDI transmits knowledge through demonstration effect, labor mobility and backward and forward linkages between foreign firms and local buyers and suppliers (Wang and Blomstrom 1992; Borensztein et al. 1998). It also increases competition in the local market, which has two opposing effects on the productivity of domestic firms: on the one hand, it pushes local firms to be more innovative and productive; on the other hand, it causes foreign firms to be more secretive about their technology, decreasing the probability of technology transfers from foreign to domestic firms (Javorcik 2004). With the availability of good quality micro level data during recent years, more studies find conclusive evidence that efficiency seeking FDI plays an important role in promoting innovation and productivity in emerging market economies (i.e., Wooster and Diebel 2010).

International trade facilitates knowledge transmission through learning by importing and exporting, larger market size and increased competition (Eaton and Kortum 2001; Keller 2004; Yeaple 2005; Verhoogen 2008; Bustos 2011).[2] Although there is no clear consensus in the empirical literature on the positive impact of trade on innovation and productivity, a large number of studies show that trade is an important stimulator for firms' performance in both developing and developed economies (i.e., Harrison 1996; Harrison and Hanson 1999; Edwards 2006; Melitz 2003; Bernard et al. 2006; Liao et al. 2009; Daumal and

[2] Firms importing capital- and technology-intensive products learn about new products and ideas produced elsewhere, while exporting allows firms to learn from their customers and competitors in international markets. Both imports and exports also increase the competitive pressure on firms, causing them to become more productive and innovative.

Özyurt 2011). Effects of R&D spillovers within the same industry have also been studied extensively in the literature (i.e., Griliches 1992; Jaffe 1986). The findings tend to show that R&D of neighboring firms has a positive impact on firms with high R&D capacity, but it has a negative impact on firms with lower R&D capacity (i.e., Jaffe 1986).

Empirical evidence on the R&D-productivity nexus in emerging market economies varies. East and Southeast Asian economies, such as China and the Asian Tigers, are among the most frequently cited economies as successfully utilizing both their own R&D and international knowledge diffusion channels to spur high growth and productivity rates (Kim 1980; Hobday 1995; Hu et al. 2005; Singh 2006; Chuang and Lin 1999; Liao et al. 2009; Todo et al. 2011; Ang and Madsen 2011; Yang and Chen 2012; Hou and Mohnen 2013). These economies share many features such as well-developed human capital stock at the beginning of their takeoff, strong government commitment to integration in the global economy and to the promotion of scientific and engineering capacity and technology-intensive industries.

Studies of other emerging economies, such as India, Brazil, Mexico, and Argentina provide strong evidence that international technology diffusion has a positive impact on output and productivity in these economies (Basant and Fikkert 1996; Parameswaran 2009; Madsen et al. 2010; Goedhuys 2007; Banda and Verdugo 2011; Bustos 2011). However, only a limited number of studies assess the effect of R&D on productivity in these economies, and they provide mixed results. It seems that R&D increases productivity in Argentina mainly through its impact on innovation (Chudnovsky et al. 2006; Arza and Lopez 2010). Even though innovation has a positive impact on productivity in Brazil, the effect of R&D appears to be realized in the long term (Goedhuys 2007; Kannebley et al. 2010). The majority of the studies on India offer either no evidence or weak evidence (i.e., Raut 1995; Basant and Fikkert 1996; Parameswaran 2009; Madsen et al. 2010) except for a recent study, which shows that R&D increases total factor productivity in the pharmaceutical sector in India (Sharma 2012).

With regard to Turkey, to the best of our knowledge, there is no study examining the linkages between R&D, knowledge diffusion and productivity. Among the existing studies on R&D, Lenger and Taymaz (2006) show that R&D intensity promotes innovation (which in turn promotes output) in manufacturing firms in Turkey, and Ozcelik and Taymaz (2008) provide evidence that government support programs for R&D together with technology transfers encourage private R&D investment. Meschi et al. (2011), on the other hand, points out a positive effect of R&D expenditure and foreign technology on skill upgrading, while Erdil and Pamukcu (2011) demonstrate that subsidiaries of multinational companies in Turkey collaborate on R&D projects with other affiliates of the parent company and transfer new technology from their R&D center.

On the linkages between international technology diffusion and productivity in Turkey, Taymaz and Saatci (1997) show that foreign ownership has a positive impact on the technical efficiency of firms in the motor vehicles industry. Pamukcu (2003) draws attention to the positive impact of machinery imports on firms' innovation decisions but finds that technology licensing, exporting and foreign partnership had no significant impact. Lenger and Taymaz (2006) find that foreign firms transfer more technology from abroad than their domestic counterparts, but their R&D efforts do not have a significant impact on domestic firms. They show that technology transfer from foreign firms to domestic firms mainly takes place through labor turnover. Yasar and Morrison Paul (2007, 2009) conclude that all channels of knowledge diffusion, including exports, imports, FDI and technology licensing, increase productivity in the textile, apparel and motor vehicle industries, and FDI has a stronger impact on productivity in smaller plants in the motor vehicles and parts industry.

4 Data and descriptive statistics

Data are retrieved from the Industry and Service Statistics Database, which has been compiled annually since 2003 by the Turkish Statistical Institute and covers nationally representative firms of all sizes in the service and manufacturing sectors. After excluding non-manufacturing firms and firms with fewer than 20 employees, our dataset includes 8561 manufacturing firms active in 11 sectors during 2003–2007, providing us with 42,111 observations.[3] All monetary series are in Turkish liras and deflated using a 4-digit industry level deflator with 2003 as the base year. Stock values of R&D and technology diffusion variables are computed using the perpetual inventory method with a 15 % depreciation rate.[4] As widely cited in the literature, R&D stock is a better proxy for firms' R&D efforts than R&D flows given that the impact of R&D efforts persists over several years (i.e., Griliches 1980).

Following non-scale endogenous growth literature, the analysis uses in-house R&D intensity, defined as in-house R&D stock per worker. Firms that conducted R&D at least once between 2003 and 2007 are referred to as "R&D

[3] These 11 manufacturing industries are chemicals, communications, electrical, food, furniture, machinery, metal, publishing, textile, transport and wood and paper.

[4] The description of the main variables of interest are reported in Table 6 and the correlation coefficients among them computed using balanced data of R&D firms are reported in Table 7 in the Appendix.

firms"—constituting 28 % of the full sample, 27 % of domestic firms and 50 % of foreign firms. "Foreign" or "foreign-owned" firms are those with foreign ownership of 10 % or more, constituting about 4.3 % of the full sample.

Table 1 shows the descriptive statistics of R&D firms and non-R&D firms across the full sample as well as among domestic and foreign firms. As seen in the first row of the table, a higher percentage of R&D firms than non-R&D firms are foreign-owned (7.5 and 3 %, respectively). An average of 44.8 % of the R&D firms annually conducted R&D and 43.3 % conducted in-house R&D over the 2003–2007 period. These figures were higher for foreign R&D firms (60.4 and 43.3 %, respectively) than domestic R&D firms (58.1 and 41.9 %, respectively). Higher percentages of R&D firms of all types (domestic or foreign) than non-R&D firms engaged in international trade and licensed technology—foreign R&D firms having higher percentages on both indicators than domestic R&D firms.

During 2003–2007, as Table 1 shows, a typical R&D firm in Turkey allocated 65.8 % of its total R&D expenditure to in-house R&D—a share amounting to about 73.8 % for domestic R&D firms and 56.9 % for foreign R&D firms. Although foreign R&D firms had much larger average in-house R&D intensity than domestic R&D firms—1753 Turkish liras (TL) and 690 TL, respectively—they allocated only a slightly larger average share of manufacturing revenue (0.7 %) to in-house R&D than did domestic R&D firms (0.6 %). The data also show that foreign R&D firms have nearly twice the technological capability of their domestic counterparts, which is not surprising given that they tend to invest more in R&D than domestic R&D firms.

In addition, R&D firms took better advantage than non-R&D firms of knowledge diffusion channels (such as technology licensing, share of foreign ownership, imports and exports)—and foreign R&D firms did so more than domestic R&D firms. Moreover, as expected, both foreign and domestic R&D firms outperformed their non-R&D counterparts in average number of employees, capital stock per worker and labor productivity, both when measured as value added per worker and as manufacturing revenue per worker. Finally, non-R&D foreign firms had the highest concentration of large firms in their industries, followed by foreign R&D firms; non-R&D domestic firms had the lowest concentration of large firms.[5]

5 Methodology and empirical strategy

Our econometric model is based on the standard Cobb-Douglas production function of non-scale endogenous growth theories of Aghion and Howitt (1998), Young (1998), and Dinopoulos and Thompson (2000), which model aggregate output as a function of endogenously created technological innovation, capital stock and labor:

$$Y_{it} = A_{it} K_{it}^{\alpha} L_{it}^{1-\alpha} \quad (1)$$

where Y, A, K and L are aggregate levels of output, technological innovation, capital and labor, respectively, and i and t are firm and year subscripts. Technological innovation A is determined by R&D stock and various knowledge transmission mechanisms:

$$A_{it} = R_{it}^{\beta} D_{it}^{\delta} \quad (2)$$

where R_{it} is in-house R&D stock and D_{it} denotes various knowledge diffusion channels, including trade share of revenue, share of foreign ownership, industry level R&D spillovers and R&D spillovers from foreign-owned firms in the same industry and technology licensing. Substituting Eq. (2) into (1), dividing it by labor (L), and taking natural log gives us the following baseline equation:

$$y = \alpha_1 k_{it} + \alpha_2 r_{it} + \alpha_3 tr_{it} + \alpha_4 for_{it} + \alpha_5 rs_{it} + \alpha_6 rs_{for,it} + \alpha_7 tl_{it} \quad (3)$$

where y is labor productivity measured by per worker value added of a firm; k is per worker physical capital; r is R&D intensity measured by in-house R&D stock per worker; tr is trade share of revenue; for is the share of foreign ownership in a firm; rs is R&D spillovers from other firms in the same 4-digit industry; rs_{for} is R&D spillovers from foreign firms in the same 4-digit industry and tl is technology licensing. The regression equation is derived by adding to the above equation an indicator on the technological capability of firms, Herfindahl index, interaction terms of technological capability with in-house R&D intensity and four channels of knowledge diffusion—namely trade, industry level R&D spillovers, R&D spillovers from foreign firms in the same industry and technology licensing—as well as industry and year dummies:

[5] Descriptive statistics of R&D firms across 11 industries in the data are provided in Table 8 in the Appendix. Transport, food and communications are the largest industries—as measured by the number of employees. Communications industry also has the highest share of R&D firms in the total sample—as well as the highest in-house R&D intensity—followed by the electrical, machinery and transport industries. Transport has by far the highest share of foreign R&D firms, followed by chemicals, food, communications and wood and paper. Regarding the knowledge diffusion channels, the chemicals industry licenses the highest technology per worker, followed by the publishing and food industries. Communications and wood and paper have the highest share of imports, while textile and transport have the highest share of exports. The industries with the highest value added per worker are chemicals and wood and paper, and with the highest manufacturing revenue per worker are food, wood and paper and chemicals.

Table 1 Percent share and mean values of key variables across different groups of firms over the period 2003–2007

	R&D firms	Non R&D	Domestic R&D	Foreign R&D	Domestic non-R&D	Foreign non-R&D
Number of observations	11,798	30,313	10,812	887	29,314	915
Number of firms	2359	6062	2162	177	5862	183
Foreign firms (%)	7.5	3.0	0.0	100	0.0	100
Firms conducting R&D (%)	44.8	0.0	43.3	60.4	0.0	0.0
Firms conducting in-house R&D (%)	43.3	0.0	41.9	58.1	0.0	0.0
Firms engaging in trade (%)	76.7	56.7	75.1	94.1	55.6	89.1
Firms licensing technology (%)	44.5	27.0	41.7	75.1	26.0	59.2
In-house R&D/total R&D (%)	65.8	0.0	73.8	56.9	0.0	0.0
In house R&D/labor (TL)	770	0.0	690	1753	0.0	0.0
In house R&D/revenue (%)	0.7	0.0	0.6	0.7	0.0	0.0
Technological capability (%)	19.3	0.0	18.2	31.4	0.0	0.0
Licensed technology/labor (TL)	640	481	598	1146	449	1467
Foreign ownership share (%)	5.4	2.2	0.0	71.9	0.0	72.2
Imports/revenue (%)	10.0	5.4	8.8	23.4	5.0	17.3
Exports/revenue (%)	19.4	15.3	18.6	26.9	14.7	33.7
Value added/labor (1000 TL)	41	28	38	85	26	79
Revenue/labor (1000 TL)	133	97	124	245	93	241
Labor	237	96	206	544	92	225
Depreciation allowance/labor (TL)[a]	4847	3109	4444	9511	2907	9484
Herfindahl Index (%)	15.7	13.7	15.5	17.6	13.5	19.2

All monetary variables are in Turkish Liras and deflated using 4-digit industry level deflators

[a] Following the previous studies examining the manufacturing firms in Turkey, depreciation allowance is used to proxy for capital stock given that there were many zeros in investment data. Revenue refers to manufacturing revenue

$$\begin{aligned} y_{it} = {} & \alpha_0 + \alpha_1 k_{it} + \alpha_2 r_{it} + \alpha_3 tr_{it} + \alpha_4 for_{it} + \alpha_5 rs_{it} \\ & + \alpha_6 rs_{for,it} + \alpha_7 tl_{it} + \alpha_8 tc_{it} + \alpha_9 hf_{it} + \alpha_{10}(r * tc)_{it} \\ & + \alpha_{11}(tr * tc)_{it} + \alpha_{12}(rs * tc)_{it} + \alpha_{13}(rs_{for} * tc)_{it} \\ & + \alpha_{14}(tl * tc)_{it} + \beta_1 i + \beta_2 t + \varepsilon_{it}. \end{aligned} \quad (4)$$

where *tc* proxies the technological capability of a firm and is measured as the ratio of a firm's in-house R&D stock to the average in-house R&D stock of the technological frontier in the same industry, and *hf* refers to Herfindahl index that measures industry level market concentration and is included in the model to control for the effect of the presence of large firms on the productivity rates of firms in the same industry.[6] The five interaction terms in the above equation measure the impact of technological capability (*tc*) on the effectiveness of in-house R&D intensity and four knowledge diffusion channels mentioned above in promoting productivity.[7]

Industry (*i*) and year (*t*) *d*ummies are included in the specification of all regression models to account for the time invariant heterogeneity across industries and common shocks to firms over time. The log transformed series are normally distributed and first differenced data do not have autocorrelation and potential heteroskedasticity is taken into consideration by using Windmeijer-corrected robust standard errors.

There is strong evidence in the literature that firms with higher absorptive capacity and technological capability enjoy higher productivity rates and are able to utilize their own R&D and knowledge diffusion channels better than other firms (i.e., Kim 1980; Cohen and Levinthal 1990; Yasar 2013). To investigate whether this holds true for manufacturing firms in Turkey, we included in our econometric model a technological capability variable (*tc*) mentioned above and interacted it with knowledge diffusion channels and in-house R&D intensity. It is expected that the higher a firm's R&D investment compared with that of the technology frontier in the same industry, the higher its technological capability will be (Kokko 1994), leading it to utilize both in-house R&D and knowledge diffusion channels more effectively than other firms to increase its productivity. All knowledge diffusion channels as well as in-house R&D and Herfindahl index enter the production function through

[6] Industries with high market concentration are shown to have higher R&D intensity (Scherer 1995) and growth rates provided that the market power of firms is not too high (Smulders and van de Klundert 1995).

[7] The descriptions and the summary statistics of these variables and their correlation coefficients computed using balanced data of R&D firms are presented in Tables 6 and 7 in the Appendix.

innovation function, thus serve as shift variables (i.e., Yasar and Morrison Paul 2012; Kokko 1994).

Equation (4) is first estimated by a baseline ordinary least squares (OLS) estimation that takes into account first order autocorrelation (AR1), industry fixed effects, year effects and heteroskedasticity, followed by two-step system GMM analyses developed by Blundell and Bond (1998) that control for endogeneity problems. We employed system GMM instead of difference GMM analysis because the latter has poor precision when the series are persistent and yields less-efficient estimators when the number of time series observations is small (Blundell and Bond 1998).[8] In addition, two-step system GMM is preferred over one-step system GMM as the main regression technique because its estimator is shown to be more efficient and robust to heteroskedastic error terms over time and across cross-sectional units (Blundell and Bond 1998; Roodman 2006; Hayakawa 2014). The potential finite sample bias associated with two-step system GMM is accounted for through Windmeijer-corrected robust standard errors (Windmeijer 2005). One-step system GMM is applied as a sensitivity analysis of the main model.

Three conditions are required for System GMM results to be reliable: (a) the number of cross-sectional units should be higher than the number of instruments, (b) the instruments should be valid and (c) there should not be second-order autocorrelation in the series. Since all variables of interest in the model are potentially endogenous to productivity, we instrumented all of them with their second, third and fourth lags.[9] The maximum number of instruments used in the regression models is 96 for the full sample and 91 for the sample of domestic firms (about 5 % of the firms in each sample). All models have valid instruments and no second-order autocorrelation. In addition, following the previous studies that used similar firm level data from the Turkish Statistics Office (Taymaz and Saatci 1997; Yasar and Morrison Paul 2009), we employ a depreciation allowance to proxy for physical capital instead of the accumulation of investment series, as the latter has many zero observations.

Except for trade share of revenue, technological capability, foreign ownership and Herfindahl index, all variables are normalized by labor and are in natural log. All regressions use balanced panel data from 1895 manufacturing firms that conducted R&D at least once during 2003–2007, providing us with 7580 observations, and include lagged dependent variable, industry and year dummies. Standard errors of all regressions are corrected for heteroskedasticity as well as finite sample bias in the case of the two-step system GMM analysis.

6 Results

Benchmark results obtained from the OLS analysis that include industry and year dummies and lagged dependent variable are reported in Table 2. As observed, most variables are significant and have the expected signs. However, given the potential endogeneity issues in the model, OLS results merely reveal the correlations between variables. To mitigate endogeneity issues, we employed the two-step system GMM technique as our main regression model. All regressions include a lag dependent variable, and the test results for the validity of instruments and the presence of first- and second-order autocorrelation are reported at the end of the tables.

Table 3 reports the findings of the two-step system GMM analysis. Among the variables of interest, foreign ownership share and licensed technology as well as the interaction terms between technological capability and in-house R&D intensity and R&D spillovers from FDI remain significant with the expected signs. Different from the OLS results, the first lag of the dependent variable, capital stock, in-house R&D, trade, Herfindahl index and the interaction term between technological capability and trade become insignificant. In addition, the sign of the coefficient of R&D spillovers switches from positive to negative, and the interaction term between technological capability and licensed technology becomes significant with a positive sign.

Given that most of the firms in our sample are domestic firms with no foreign ownership, and that one of our main objectives is to investigate the impact of R&D and knowledge diffusion on the productivity of domestic firms, we also reported the findings of the two-step system GMM analysis for domestic firms only. As seen in Table 4, the results are similar to those reported in Table 3, except that the magnitudes of the coefficients of the interaction terms are larger than those obtained from the full sample.[10]

[8] System GMM estimates the system of the level and first-difference equations using the lagged levels of the series as instruments for the difference series, and the lagged difference series as instruments for the level series. Difference GMM estimates only the first-difference equation using the lagged levels of the series as instruments.

[9] The first lag of the dependent variable is also instrumented. The results of the two-step system GMM regressions that did not instrument the first lag of the dependent variable are very similar to the results reported here, except that the coefficient of the first lag of the dependent variable is significant in those regressions.

[10] Findings of the one-step system GMM analyses for both the full sample and the sample of domestic firms were similar to those of the two-step system GMM results. The only differences were that: in the full sample, two out of six regressions did not pass the AR2 test (i.e., p values were 0.07 and 0.08), and the interaction term between technological capability and R&D spillovers from foreign firms was not significant; in the sample of domestic firms, the interaction term between technological capability and in-house R&D was not significant.

Table 2 OLS regression analysis of labor productivity, full sample, 2003–2007

	(1)	(2)	(3)	(4)	(5)	(6)
1st lag of labor productivity	0.534***	0.534***	0.534***	0.535***	0.534***	0.534***
	[0.014]	[0.014]	[0.014]	[0.014]	[0.014]	[0.014]
Capital stock/labor	0.045***	0.045***	0.045***	0.045***	0.045***	0.045***
	[0.003]	[0.003]	[0.003]	[0.003]	[0.003]	[0.003]
In-house R&D stock/labor	0.020***	0.019***	0.020***	0.021***	0.020***	0.021***
	[0.003]	[0.003]	[0.003]	[0.003]	[0.003]	[0.003]
Trade/revenue	0.000	0.000	0.000*	0.000	0.000	0.000
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Foreign ownership share	0.003***	0.003***	0.003***	0.003***	0.002***	0.003***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
R&D spillovers/labor	0.005	0.004	0.005*	0.006	0.005	0.005
	[0.003]	[0.003]	[0.003]	[0.004]	[0.003]	[0.003]
R&D spillovers from FDI/labor	0.006***	0.006***	0.006***	0.006***	0.005**	0.006***
	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]
Licensed technology stock/labor	0.021***	0.021***	0.021***	0.021***	0.021***	0.020***
	[0.003]	[0.003]	[0.003]	[0.003]	[0.003]	[0.003]
Technological capability (TC)	0.092***	−0.075	0.124***	0.105**	0.075***	0.068
	[0.022]	[0.091]	[0.031]	[0.045]	[0.023]	[0.049]
Herfindahl index	0.133***	0.138***	0.130**	0.131**	0.143***	0.133***
	[0.051]	[0.051]	[0.051]	[0.051]	[0.051]	[0.051]
TC*in-house R&D/labor		0.021*				
		[0.011]				
TC*trade/revenue			−0.001*			
			[0.001]			
TC*R&D spillovers/labor				−0.002		
				[0.005]		
TC*R&D spillovers from FDI/labor					0.014**	
					[0.006]	
TC*licensed technology stock/labor						0.004
						[0.007]
Number of observations	7580	7580	7580	7580	7580	7580
R-squared	0.521	0.521	0.521	0.521	0.522	0.521

Standard errors are in brackets. abor productivity is measured as per worker value added. All regressions include year and industry dummies and a constant term. All variables except for foreign ownership, Herfindahl index and technological capability are in natural log. Revenue refers to manufacturing revenue

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Since our model employs interaction terms of technological capability with R&D intensity and knowledge diffusion channels, the parameters of these variables reported in Tables 3 and 4 no longer indicate their average impact on productivity.[11] To assess how increases in R&D intensity and knowledge diffusion channels affect productivity, we need to compute the marginal effects of these variables at different levels of technological capability. First, however, it is important to note some key properties of interaction models. As demonstrated by Brambor et al. (2006), interaction models should include all individual indicators constituting the interaction term to avoid major inferential errors. Moreover, it is highly likely that the correlation between constituent variables and their interaction terms will be high as they are closely related.

[11] The coefficients of the individual indicators constituting the interaction term (for example X in X*Y) capture the effect of the individual indicator (X) on the dependent variable when the other indicator of the interaction term (Y) is zero.

Table 3 Two-step system GMM regression analysis of labor productivity, full sample, 2003–2007

	(1)	(2)	(3)	(4)	(5)	(6)
1st lag of labor productivity	0.066	0.144	0.031	0.088	0.112	0.145
	[0.126]	[0.127]	[0.124]	[0.120]	[0.124]	[0.113]
Capital stock/labor	0.026	0.028	0.022	0.036	0.035	0.045
	[0.028]	[0.027]	[0.027]	[0.026]	[0.027]	[0.027]
In-house R&D stock/labor	0.011	0.013	0.009	0.016	0.014	0.018
	[0.012]	[0.011]	[0.012]	[0.012]	[0.012]	[0.011]
Trade/revenue	0.000	0.001	0.000	0.001	0.002	0.002
	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]
Foreign ownership share	0.013***	0.010***	0.013***	0.011***	0.011***	0.012***
	[0.004]	[0.003]	[0.004]	[0.004]	[0.004]	[0.004]
R&D spillovers/labor	−0.035***	−0.033***	−0.036***	−0.033**	−0.033**	−0.039***
	[0.013]	[0.012]	[0.013]	[0.013]	[0.013]	[0.013]
R&D spillovers from FDI/labor	−0.006	−0.004	−0.007	0.000	−0.009	−0.010
	[0.013]	[0.012]	[0.013]	[0.013]	[0.012]	[0.012]
Licensed technology stock/labor	0.026**	0.026**	0.026**	0.025**	0.023*	0.014
	[0.013]	[0.012]	[0.013]	[0.012]	[0.012]	[0.013]
Technological capability (TC)	0.079	−0.569	0.143	−0.194	0.045	−0.334*
	[0.075]	[0.391]	[0.141]	[0.159]	[0.079]	[0.181]
Herfindahl index	0.424	0.311	0.394	0.225	0.393	0.130
	[0.392]	[0.360]	[0.369]	[0.335]	[0.372]	[0.338]
TC*in-house R&D/labor		0.082*				
		[0.047]				
TC*trade/revenue			−0.001			
			[0.003]			
TC*R&D spillovers/labor				0.042**		
				[0.018]		
TC*R&D spillovers from FDI/labor					0.037*	
					[0.020]	
TC*licensed technology stock/labor						0.061***
						[0.023]
Number of observations	7580	7580	7580	7580	7580	7580
Number of firms	1895	1895	1895	1895	1895	1895
Hansen test (*p* value)	0.289	0.906	0.942	0.900	0.945	0.954
AR1 test (*p* value)	0.000	0.000	0.001	0.000	0.000	0.000
AR2 test (*p* value)	0.116	0.481	0.933	0.748	0.626	0.402

Standard errors are in brackets. Labor productivity is measured as per worker value added. All regressions include year and industry dummies and a constant term. All variables except for foreign ownership, Herfindahl index and technological capability are in natural log. Revenue refers to manufacturing revenue

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

However, this does not pose a significant problem for the inference of the model given that the main parameters of interest are not the coefficients of constituent variables or interaction terms but the marginal effects of the constituent variables, and their standard errors are not affected much by multicollinearity (Brambor et al. 2006).

Table 5 documents the marginal effects of in-house R&D and knowledge diffusion channels on labor productivity at minimum, mean and maximum values of technological capability using the parameters of the two-step system GMM analyses reported in Tables 3 and 4.[12] As seen from Table 5, a 1 % increase in in-house R&D

[12] Minimum and maximum values of technological capability is zero and 5, respectively, for both the full sample and the sample of domestic firms. Its mean value is 0.188 for the full sample and 0.173 for the sample of domestic firms.

Table 4 Two-step system GMM regression analysis of labor productivity, domestic firms only, 2003-2007

	(1)	(2)	(3)	(4)	(5)	(6)
1st lag of labor productivity	0.050	0.118	0.009	0.042	0.182	0.132
	[0.153]	[0.138]	[0.156]	[0.138]	[0.154]	[0.130]
Capital stock/labor	0.012	0.021	0.006	0.027	0.011	0.037
	[0.029]	[0.026]	[0.030]	[0.028]	[0.029]	[0.028]
In-house R&D stock/labor	0.008	0.010	0.007	0.014	0.012	0.017
	[0.013]	[0.012]	[0.013]	[0.012]	[0.013]	[0.012]
Trade/revenue	0.000	0.000	0.001	0.001	0.001	0.002
	[0.003]	[0.002]	[0.002]	[0.002]	[0.003]	[0.002]
R&D spillovers/labor	−0.033**	−0.031**	−0.037**	−0.033**	−0.034**	−0.040***
	[0.014]	[0.014]	[0.015]	[0.014]	[0.014]	[0.015]
R&D spillovers from FDI/labor	−0.017	−0.015	−0.016	−0.009	−0.013	−0.016
	[0.014]	[0.013]	[0.013]	[0.013]	[0.013]	[0.013]
Licensed technology stock/labor	0.029**	0.027**	0.029**	0.027**	0.025*	0.013
	[0.014]	[0.013]	[0.014]	[0.013]	[0.013]	[0.014]
Technological capability (TC)	0.088	−0.676	0.082	−0.250	0.024	−0.419*
	[0.091]	[0.466]	[0.168]	[0.192]	[0.090]	[0.225]
Herfindahl index	0.522	0.425	0.595	0.350	0.555	0.184
	[0.427]	[0.371]	[0.399]	[0.358]	[0.422]	[0.350]
TC*in-house R&D/labor		0.098*				
		[0.058]				
TC*trade/revenue			−0.000			
			[0.004]			
TC*R&D spillovers/labor				0.053**		
				[0.022]		
TC*R&D spillovers from FDI/labor					0.077**	
					[0.038]	
TC*licensed technology stock/labor						0.078***
						[0.028]
Number of observations	6724	6724	6724	6724	6724	6724
Number of firms	1681	1681	1681	1681	1681	1681
Hansen test (p-value)	0.954	0.977	0.950	0.973	0.909	0.977
AR1 test (p-value)	0.009	0.001	0.017	0.004	0.001	0.000
AR2 test (p-value)	0.906	0.722	0.745	0.857	0.505	0.634

Standard errors are in brackets. Labor productivity is measured as per worker value added. All regressions include year and industry dummies and a constant term. All variables except for foreign ownership, Herfindahl index and technological capability are in natural log. Revenue refers to manufacturing revenue

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

intensity leads to about a 0.3 % increase in labor productivity within firms with average technological capability—in both the full sample and the sample of domestic firms—while leading to a 0.43 % and 0.50 % increase within firms with maximum technological capability in the full sample and the sample of domestic firms, respectively. Consistent with the view developed by Gerschenkron (1962), Cohen and Levinthal (1990) and Lall (1992), these results suggest that firms' technological capability plays a critical role in effectively utilizing R&D investment to promote productivity.

Interestingly, although industry level R&D spillovers have a significant negative impact on productivity among firms with lowest technological capability—in both the full sample and the sample of domestic firms—this effect decreases as the firms' technological capability moves from lowest to average. It becomes positive among firms with maximum technological capability. This is not surprising, because firms with low technological capability are less likely to benefit from knowledge diffusion due to their low absorptive capacity and to be competitive against firms with high R&D investment.

Table 5 Marginal effects of interaction terms on labor productivity

	Full sample			Domestic firms		
	Min	Mean	Max	Min	Mean	Max
In-house R&D stock/labor	0.013	0.029**	0.425*	0.010	0.027*	0.497*
	[0.011]	[0.015]	[0.237]	[0.012]	[0.016]	[0.290]
Trade/revenue	0.000	0.000	−0.006	0.001	0.001	0.000
	[0.002]	[0.002]	[0.013]	[0.002]	[0.002]	[0.018]
R&D spillovers/labor	−0.033***	−0.025**	0.179**	−0.033**	−0.024*	0.230**
	[0.013]	[0.012]	[0.089]	[0.014]	[0.014]	[0.107]
R&D spillovers from FDI/labor	−0.009	−0.002	0.175*	−0.013	0.001	0.372**
	[0.012]	[0.012]	[0.098]	[0.013]	[0.013]	[0.187]
Licensed technology stock/labor	0.014	0.025**	0.321***	0.013	0.026**	0.402***
	[0.013]	[0.012]	[0.112]	[0.014]	[0.013]	[0.136]

Standard errors in brackets

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Similarly, R&D spillovers from foreign firms in the same industry promote productivity only when firms attain the highest level of technological capability. This finding holds true in both the full sample and the sample of domestic firms, though these spillovers have a much higher impact on the productivity of the latter. Moreover, technology licensing increases the productivity of firms with average and higher technological capability, although its impact is higher on the productivity of domestic firms than on the full sample. Finally, as seen from Table 5, international trade has no significant impact on productivity at any level of technological capability in either sample.

Taken all together, this study—the first to examine the interlinkages between R&D, knowledge diffusion channels and labor productivity in manufacturing firms in Turkey—finds that the effect of in-house R&D intensity on the productivity of manufacturing firms in Turkey depends on the level of the firms' technological capability: no significant impact is observed at the minimal level of technological capability, but positive significant impacts are observed at the average and maximum levels. These findings suggest that Turkey should foster R&D investment to increase firms' technological capability and productivity. Although Turkey's R&D share of GDP has increased during the past decade, reaching to 0.84 % of GDP in 2010, it still falls below the average R&D investment of emerging economies (1.26 %), Brazil (1.16 %) and China (1.76 %).

While none of the previous studies examined the impact of R&D on firms' productivity in Turkey, some studies investigated the relationship between R&D and other performance indicators of firms. Among these, Lenger and Taymaz (2006) find that R&D intensity increases firms' innovativeness, which in turn increases their output. Similarly, Ar and Baki (2011) find that the R&D efforts of firms in Turkey's science and technology parks have had a positive impact on their product innovation, thus promoting the firms' performance, measured as sales, profitability and market share.

Regarding the five knowledge diffusion channels examined here, we find that the average impact of foreign ownership share and technology licensing on firms' productivity is consistently positive and significant. However, when the impact of technology licensing on productivity is made conditional on technological capability, its marginal impact becomes significant only above a threshold of technological capability. Industry level R&D spillovers and R&D spillovers from foreign firms in the same industry positively affect firms' productivity only among firms with above average technological capability.[13] In addition, average impact of industry level R&D spillovers on productivity—as well as their marginal impact at the minimal and average levels of technological capability—are negative. This suggests that firms need to acquire relatively high technological capability in order to benefit from knowledge created by other R&D firms in the same industry and to be able to compete with them. Finally, the results show no significant relationship between international trade and productivity in either of the sample at any level of technological capability.

Consistent with our findings on foreign ownership share reported above, several studies such as Taymaz and Saatci (1997) and Yasar and Morrison Paul (2007, 2009) found that foreign ownership has a positive impact on productivity in Turkey. Although Lenger and Taymaz (2006) could not find significant R&D spillovers from foreign to domestic firms between 1997 and 2000, they showed that

[13] The exact level of technological capability at which the impact of constituent variables become significant is not measured.

technology is transferred from foreign firms to domestic firms through labor turnover. Furthermore, Darrat and Sarkar (2009) provided strong evidence for a positive long-term impact of FDI on growth in Turkey. Similar to our results, Yasar and Morrison Paul (2007, 2009) also found that technology licensing promotes the productivity of manufacturing firms in Turkey.

Since the beginning of the 2000s, Turkey has taken big steps to promote its FDI inflows, which resulted in an impressive increase in FDI share of GDP—from annual averages of 0.37 % between 1996 and 2000 to 2.5 % between 2006 and 2010. However, there is still plenty of room for the country to improve both the amount and the quality of its FDI inflows. Specifically, Turkey's FDI share of GDP is still below the average FDI share of emerging economies, and compared with other leading emerging economies, it has a lower share of R&D-intensive FDI. As pointed out by Karabag et al. (2010), although Turkey has some advantages in cost and availability of well-educated personnel, it lacks strong pull factors for R&D-intensive FDI, such as large-scale investment and production in capital-intensive industries, R&D upgrading in local firms and initiative from private capital owners to collaborate with international firms.

7 Conclusion

This paper analyzed the impact of in-house R&D intensity and various knowledge diffusion channels on the productivity of manufacturing firms in Turkey using a large panel dataset from the Turkish Statistics Office between 2003 and 2007. We find that the impact of in-house R&D intensity on the productivity of Turkish manufacturing firms is conditional on their technological capability: only above a threshold of technological capability do the firms reap the productivity benefits from their R&D investment. Among the five knowledge diffusion channels covered in this paper, foreign ownership share and technology licensing have a strong positive effect on the productivity of firms, although the conditional effect of technology licensing is significant only above a threshold of technological capability. Moreover, industry level R&D spillovers and R&D spillovers from foreign firms in the same industry increase productivity of firms only when firms have above average technological capability. Trade share of revenue has no significant impact on firms' productivity.

These results are in line with the findings of recent literature on emerging market economies, which suggest strong linkages between knowledge diffusion and productivity but either weaker or conditional linkages between R&D and productivity. The only exceptions to this are among the emerging economies of East and Southeast Asia, where productivity seems to have a strong positive association with both knowledge diffusion and R&D.

As the experiences of newly industrialized economies have shown, emerging economies can successfully tap the international knowledge pool to promote their R&D, innovation capacity and productivity. In fact, exploiting international knowledge sources is the most viable strategy for these economies, given their limited technological capacity and resources for large R&D investment. That both R&D efforts and most knowledge diffusion channels positively affect firms' productivity in Turkey, conditional on their technological capability, reveals that Turkish firms, when technically enabled, can successfully utilize R&D and can process the know-how of foreign firms and technology produced outside Turkey to increase their production.

Even though Turkey has well-developed human capital capacity and strong links to the global economy, it still lags far behind the leading emerging economies in its R&D efforts, FDI inflows and technology licensing, which are of high importance for middle-income economies to foster their innovation capacity and productivity. Therefore, if Turkey is to soon join the ranks of the high-income economies, it needs to accelerate R&D capacity building and use of the international knowledge pool while gradually moving from imitation to innovation of new ideas.

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Appendix 1

See Table 6.

Table 6 Definitions and descriptive statistics of the variables used in the regression analysis

Variable name	Definition	Mean	
		Full N: 7580	Domestic N:6840
Labor productivity	Total value added of manufacturing firms divided by number of employees	10.28 (0.96)	10.20 (0.94)
Physical capital stock per worker	Depreciation allowance of capital stock divided by number of employees	6.83 (3.03)	6.67 (3.07)
In house R&D stock per worker	Stock of total in house R&D expenditure of a firm divided by number of employees	5.57 (2.74)	5.45 (2.70)
Licensed technology stock per worker	Stock of total intangible assets bought by firms, which include technology licensing, patents, software and other intangible assets, divided by number of employees	4.18 (3.17)	3.98 (3.16)
R&D spillovers per worker	Stock of 4-digit industry level R&D expenditure of all firms, excluding firms' own R&D stock, divided by number of employees	9.63 (2.92)	9.59 (2.89)
R&D spillovers from foreign firms per worker	Stock of 4-digit industry level R&D expenditure of foreign owned firms (defined as the firms with a foreign ownership of 10 % and above), excluding firms' own R&D stock, divided by number of employees	4.28 (4.93)	4.17 (4.90)
Foreign ownership (%)	Share of total equities owned by foreign firms	6.32 (22.02)	–
Trade/revenue (%)	Sum of imports and exports of goods and services as share of total revenue	30.00 (32.8)	27.79 (31.78)
Technological capability (TC) (%)	Ratio of firms' in-house R&D stock to the average in-house R&D stock of the firm with the highest average in-house R&D stock in the same 4-digit industry during 2003–2007	0.19 (0.39)	0.17 (0.38)
Herfindahl index	Sum of the square of the market share of firms at the four-digit industry. Market share is defined as the total product stock share of a firm in its four-digit industry	0.16 (0.17)	0.15 (0.17)

All variables except for foreign ownership, Herfindahl index and technological capability are in natural logs. Figures in parenthesis are standard deviations of the means. These statistics are computed using the sample of regression models that use balanced data

Appendix 2

See Table 7.

Table 7 Correlation coefficients, full sample, 2003–2007

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Value added	1.00													
2. Depreciation allowance	0.40*	1.00												
3. In-house R&D stock	0.25*	0.14*	1.00											
4. Herfindahl Index	0.10*	0.06*	0.07*	1.00										
5. Trade/revenue	0.17*	0.16*	0.07*	−0.04*	1.00									
6. Technological capability	0.19*	0.13*	0.39*	0.30*	0.05*	1.00								
7. Foreign ownership	0.25*	0.13*	0.13*	0.01	0.17*	0.07*	1.00							
8. R&D spillovers	0.05*	0.02	0.09*	−0.32*	0.08*	−0.30*	0.07*	1.00						
9. R&D spillovers from FDI	0.07*	0.00	0.01	−0.11*	0.03*	−0.25*	0.07*	0.25*	1.00					
10. Licensed technology stock	0.34*	0.32*	0.20*	0.06*	0.15*	0.17*	0.18*	0.07*	0.05*	1.00				
11. TC*In-house R&D stock	0.22*	0.14*	0.43*	0.27*	0.06*	0.97*	0.10*	−0.23*	−0.22*	0.19*	1.00			
12. TC*Trade/revenue	0.17*	0.14*	0.29*	0.15*	0.34*	0.70*	0.13*	−0.14*	−0.14*	0.16*	0.70*	1.00		
13. TC*R&D spillovers	0.21*	0.14*	0.43*	0.15*	0.08*	0.84*	0.11*	0.00	−0.18*	0.20*	0.88*	0.66*	1.00	
14. TC*Foreign R&D spillover	0.21*	0.12*	0.27*	−0.02	0.10*	0.29*	0.25*	0.09*	0.24*	0.17*	0.35*	0.34*	0.43*	1.00
15. TC*Licensed technology stock	0.24*	0.17*	0.36*	0.24*	0.07*	0.86*	0.11*	−0.18*	−0.17*	0.36*	0.86*	0.66*	0.78*	0.34*

Significant at 10 %. TC refers to technological capability. All variables except for 4, 5, 6, 7, 12 and 15 are worker and all variables except for foreign ownership, trade share of revenue, and technology capability are in natural logs. R&D spillovers are at the 4 digit industry level

Appendix 3

See Table 8.

Table 8 Descriptive statistics of R&D firms across industries, 2003–07

	Chemicals	Communication	Electrical	Food	Furniture	Machinery	Metal	Publishing	Textile	Transport	Wood-paper
Observations of R&D firms	2491	352	675	1137	773	1485	1069	101	2627	838	250
R&D firms in full sample (%)	34.6	56.8	52.6	24.0	35.0	42.4	23.8	11.5	19.2	41.8	16.4
Foreign firms in R&D sample	11.4	9.4	8.1	9.6	5.6	5.9	3.6	0.0	1.8	20.3	9.2
R&D firms investing in-house R&D (%)	50.1	60.8	54.2	42.1	40.1	48.6	37.5	35.6	31.9	48.3	35.6
R&D firms licensing technology	48.7	46.0	49.5	45.0	37.6	42.9	41.2	37.6	40.6	53.1	42.4
In-house R&D/labor (TL)	1072	3464	945	435	344	793	301	541	341	1277	1096
Technological capability (TL)	22.2	15.8	15.3	28.1	13.1	16.9	29.1	54.8	12.9	12.5	35.1
Licensed technology/labor (TL)	1020	888	472	902	339	502	459	920	333	843	696
Foreign ownership share (%)	8.7	6.9	6.4	6.4	3.7	3.8	2.5	0.0	1.3	14.0	8.3
Imports/revenue (%)	13.7	17.9	10.7	4.7	4.4	8.5	8.6	3.1	9.0	13.5	16.7
Exports/revenue (%)	15.2	16.2	16.1	14.3	18.6	19.5	18.7	4.3	27.1	24.2	12.5
Value added/labor (1000 TL)	63	45	33	45	21	32	36	39	32	45	60
Revenue/labor (1000 TL)	173	130	149	220	83	94	137	84	83	143	189
Labor	216	282	156	349	182	197	236	124	227	390	141
Depreciation allowance (TL)	7623	4891	3554	6245	1872	3275	4175	5257	3299	5997	7913
Herfindahl index (%)	16.4	25.4	18.4	21.2	10.6	22.9	21.8	34.5	6.5	11.2	14.1

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