

A META-FRONTIER APPROACH TO MEASURE PRODUCTIVITY DIFFERENCES OF DOMESTIC AND FOREIGN AFFILIATED FIRMS¹

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Abstract. This paper aims to evaluate the performance of foreign affiliated and domestic firms in Turkish manufacturing subsectors covering the period 1992 and 2001. Due to the heterogeneity between domestic and foreign affiliated firms in terms of technology level, we construct a meta-frontier model to measure relative efficiency and technology gap ratios (TGR's) of domestic and foreign affiliated firms. We find that technical efficiencies of foreign affiliated firms are higher than domestic firms, and display a stable pattern during the investigation period. However, technology gap ratios indicate the existence of a negative relationship between the TGR's and technical efficiency of the firms in domestic subsectors. This means that technically efficient firms are in fact using the low level of technology. However the results do not indicate any significant relationship between the technical efficiency and TGR's of foreign affiliated firms.

Keywords: productivity, manufacturing subsectors, technical efficiency, meta-frontier.

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1. Introduction

An important policy recommendation for developing countries is that; they need to attract foreign capital not only to decrease the gap between savings and expenditures, but also to increase productivity levels in domestic production. In theory, local economies are expected to benefit from long lasting interactions such as labor turnovers, imita-

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tion of the superior technology, increasing competition, and commercial ties between foreign and domestic firms (Lall 1978, 1997). However, the empirical evidence² does not support this theory unanimously; and suggests that productivity benefits are not automatic, but local conditions influence firms' adoption of foreign technologies and skills (Blomstrom, Kokko 1998, 2003).

The productivity increases through foreign affiliated firms require a threshold level of human capital and absorptive capacity of local firms (Borenzstein *et al.* 1998), but even more importantly it is essential that foreign firms engage in technological activities in the local economy. However; the observations on research and development (R&D) expenditures of transnational companies show that parent firms undertake the bulk of R&D, and when these expenditures are located within affiliate firms, they are mostly in developed countries (UNCTAD 1999; UNCTAD 2005). For instance, only 13.5% of R&D expenditures by United States parent companies were located in developing countries and concentrated mostly in five countries (China, Singapore, Brazil, Mexico and the Republic of Korea) in 2002 (UNCTAD 2005).

Turkish government policy has long been pro-investment in order to attract more multinational companies. Despite its competitive advantages, which come from regional location, and relatively abundant labor force; Turkey can be considered as under-performing in attracting FDI. The efforts to attract foreign direct investments have been accelerated especially since the economic crisis of 2001. Dumludag (2009) argues that institutional factors such as enforcement mechanisms, political and economic stability, transparent legal and regulatory framework, and corruption are critical factors in explaining the behavior of the foreign direct investment inflows in Turkey. In this study, given the importance of foreign capital in economic policy, we investigate the validity of basic assumption that firms with foreign capital are more efficient than domestic firms, in the context of Turkish manufacturing industries.

The previous studies regarding the efficiency analysis of the firms premise that all firms have similar inputs as the factors of production. In other words, they assume that firms have ability to access the same production technology. The interpretation of the resulting efficiency scores relies on the validity of this crucial assumption. However, recent studies argue that firms even operating in the same industry may tend to have different production frontiers in terms of available stocks of physical, human and financial capital and economic infrastructure (O'Donnell *et al.* 2008). Due to this heterogeneity, the use

² The empirical evidence differs by sample and the methodologies employed for estimation. For example, Ramirez (2006) finds that foreign direct investment (FDI) has a positive effect for Latin America countries. Blomstrom *et al.* (1994) argue that FDI affects growth when the country is above some income level threshold. Other studies also emphasize on absorbing capacities on the host countries. Wijweera *et al.* (2010) find that FDI has a positive impact on economic growth only in the presence of a highly skilled labor. Balasubramanyam *et al.* (1996) find that openness is essential to benefit from the growth effects of FDI. However, Carkovic and Levine (2002) find that FDI does not exert a reliable, positive impact on economic growth in their panel study after controlling the endogeneity problem. Görg and Strobl (2001) also show that the results differ according to data and estimation method employed in various studies.

of standard efficiency analysis techniques like DEA (Data Envelopment Analysis) or SFA (Stochastic Frontier Analysis) might lead to misleading results, as the production technologies are not identical to make an accurate comparison.

The similar type of heterogeneity has been also observed for domestic and foreign affiliated firms in Turkish manufacturing subsectors. Based on the regressions of production functions, Lenger and Taymaz (2006), and Köymen and Sayek (2009) investigated the existence of innovation and technology spillovers between domestic and foreign manufacturing firms, and find that foreign firms have different characteristics than their domestic counterparts in terms of innovativeness and ability to transfer technology from abroad. They also find that horizontal spillovers do not have any significant contribution to the technological activities of the domestic firms in Turkey.

Although the productivity of firms in Turkish manufacturing subsectors has been previously investigated by numerous studies (See, for example, Zaim and Taşkın (1997); Bayyurt and Duzu (2008); Karadağ, Önder and Deliktaş (2002, 2005); Karadağ, Deliktaş and Önder (2004); Yılmazkuday (2009); Önder, Deliktaş and Lenger (2003); Krueger and Tuncer (1982)), we do not find any study accounting for the heterogeneity between domestic and foreign affiliated firms. In this paper, the difference between domestic and foreign affiliated firms is considered by applying meta-frontier methodology, introduced by Battese *et al.* (2002). This technique allows us to assess the performance of firms by measuring the distance of a firm belonging to either domestic or foreign group from the common meta-frontier (Rao *et al.* 2003). Based on group and meta-distance functions, we also compute technology gap ratios to compare the relative efficiency levels of domestic and foreign manufacturing firms.

The rest of the paper is organized as follows. The next section briefly summarizes the general framework of the meta-frontier methodology used in the paper. The data are introduced in section three. Section four summarizes the empirical results obtained from the application of meta-frontier. Finally the last section concludes the paper.

2. Methodology

The present paper employs meta-frontier approach, developed by Battese and Rao (2002), and O'Donnell *et al.* (2008) to account for heterogeneity among the domestic and foreign affiliated firms. Meta-frontier technique contains the calculation of a meta-technology and frontiers of homogenous groups which represents the common and the group specific technologies.

To illustrate the general framework of the approach, we construct a model including nonnegative input (x) and output (y) vectors of dimension of $(N \times 1)$ and $(M \times 1)$ respectively. Then subsectors are classified into two groups $k = 2$ as domestic and foreign, each of which are operating under a specific technology. Since the technology can be defined as a process of transforming N inputs into M outputs, the meta-technology set T^* can be considered as an envelope of all possible group technologies.

The technology set of a group can be defined as the combination of efficient production possibilities (Battese *et al.* 2004).

$$T^k = \left\{ (x, y) \in R_+^{N+M} \mid x \text{ can produce } y \right\}, \tag{1}$$

which shows the amount of N inputs x that can produce M outputs y . The input and output sets associated with the technology set T provide an equivalent representation of production technology.

The input set $L(y)$ is the set of all input vectors x which can produce y . Isoquants determine the boundaries of input set. Formally,

$$L(y) = \left\{ x : (x, y) \in T, \text{ for each } y \in R_+^M \right\}. \tag{2}$$

Similar to input set, the output set $P(x)$ associated with a specific input vector x is the set of all output vectors y which can be produced using x .

$$P(x) = \left\{ y : (x, y) \in T, \text{ for each } x \in R_+^N \right\}. \tag{3}$$

The boundary of the output set is determined by the production possibility frontier covering all optimum input output combinations. Meta-frontier can be defined as a function that envelops separate group frontiers, each of which has different technology and factor levels. In other words, the meta-frontier model is considered as an envelope of all the possible group technologies. In this case meta-technology set can be written as follows (O'Donnell *et al.* 2008):

$$T^* = \{ (x, y) : x \geq 0 \text{ and } y \geq 0, \text{ such that } x \text{ can produce } y \text{ in at least one group technology, } T^1, T^2, \dots, T^k \}. \tag{4}$$

In order to satisfy convexity of the function, meta-technology is defined as the convex hull of the union of group specific technologies (Rambaldi *et al.* 2007),

$$T^* \equiv \text{Convex Hull} \{ T^1 \cup T^2 \cup \dots T^k \}. \tag{5}$$

Since T^* satisfies all production axioms, technical efficiency can be computed by using input and output distance functions associated with the meta-technology set. Global meta-frontier defined as an envelope of all three group-specific frontiers is illustrated in Figure 1.

Hence, technical efficiency with respect to k th group technology can be written in terms of output distance function as follows,

$$TE^k = D_0(x, y) = \inf_{\theta > 0} \{ (y/\theta) \in P^k(x) \}. \tag{6}$$

This function shows the maximum degree to which a given output vector can be increased and still within the production feasibility set. Technical efficiency with respect to the meta-frontier is defined in an analogous way.

$$TE^* = D_0^*(x, y) = \inf_{\theta > 0} \{ (y/\theta) \in P^*(x) \} \text{ for all } x_t, L^*(y_t). \tag{7}$$

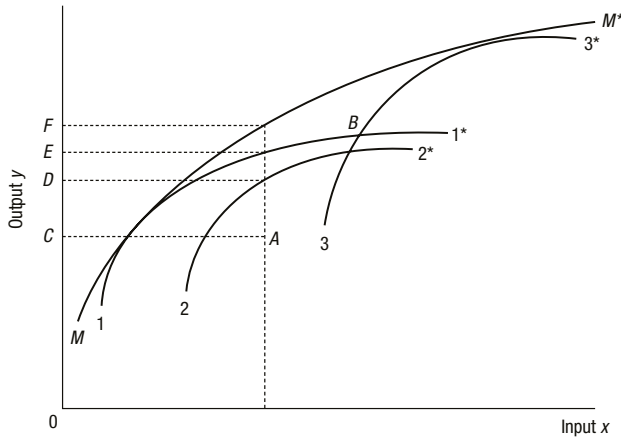


Fig. 1. Group specific frontier and meta-frontier

Source: O'Donnell *et al.* 2008: 236.

Since the meta-frontier function covers all the group specific technology by definition, the output distance function of k group frontier should be greater than or equal to the output distance function of meta-frontier.

$$D_0^k(x, y) \geq D_0^*(x, y). \tag{8}$$

Figure 1 illustrates the difference between the calculations of technical efficiency with respect to group and meta-frontier. If we take the input-output combination represented by the point A , the technical efficiency with respect to group frontier 2 showing the difference between actual and potential output can be measured as OC/OD . On the other hand, the technical efficiency with respect to meta-frontier $M-M$ can be calculated by OC/OF .

Based on the technical efficiency with respect to the group frontier and the meta-frontier in (7) and (8) one can also obtain Technology Gap Ratio (TGR) which measures the gap between the group k technology T^k and the meta-technology T^* in terms of output distance functions:

$$TGR_o^k(x, y) = \frac{D_o^*(x, y)}{D_o^k(x, y)} = \frac{TE_o^*(x, y)}{TE_o^k(x, y)}. \tag{9}$$

Equation (9) indicates that the technical efficiency relative to the meta-frontier is the product of the technical efficiency relative to frontier of the specified group and the technology gap ratio (Battese *et al.* 2004). TGR gap ratio has values between zero and one, and this implies that for a given input vector, potential output of the group technology is a certain percentage of the potential output defined by the meta-frontier. Based on this definition, TGR of point A in Figure 1 would be equal to OC/OF . As the general framework of the model shows, the calculation of meta-frontier is based on the comparison of efficiency levels of meta-frontier and the group frontiers. These measures

can be calculated by applying standard optimization techniques like DEA or SFA. SFA and DEA are the two most widely used methods to measure efficiency in the literature. In this paper we prefer DEA approach for two reasons. First, although it is sensitive to errors in data, it assumes no specific form of production function (Coelli *et al.* 2005). Second, as reported by Battese *et al.* (2004), the use of SFA may not guarantee that the estimated meta-frontier envelops the estimated group frontiers, unless linear programming is utilized.

3. Data

The methodology outlined above is applied to construct a manufacturing sector meta-frontier for Turkey. For this purpose the data covering the period between 1992 and 2001 are collected from the Turkish Statistical Institute (TURKSTAT) at the four digit level of the International Standard Industrial Classification (ISIC). According to this classification, we have 12 subsectors in the first group where the foreign affiliated firms operate. Foreign affiliated firms are private establishments with 20 or more employees and the share of foreign agents in equity equals at least 10% as categorized by TURKSTAT. The second group for the domestic firms contains 68 subsectors, hence the computation of meta-frontier is based on 80 subsectors³. Due to data limitation we use one output and two inputs in the data envelopment analysis. Total value added produced by each sector is chosen as a proxy for output, whereas annual average number of paid workers and total horsepower of installed equipment are used as proxies for the labor and the capital respectively. Descriptive properties of the data are presented in Table 1. As for domestic firms, the minimum value added is created by the subsector “spinning, weaving and finishing textiles (3211)”, whereas the maximum value added is also created by “cordage, rope and twine industries (3215)” as one of the subsector of the textile industry. On the other hand manufacture of paints, varnishes and lacquers (3521) and manufacture of motor vehicles (3843) have attained the highest and the lowest value added for foreign firms, respectively.

Table 1. Descriptive Properties of the Data in Logarithmic Values

		$\ln Q$	$\ln L$	$\ln K$
Domestic	Mean	18.514	9.553	12.007
	Std. Dev.	19.293	9.961	12.664
	Min	8.899	4.875	6.319
	Max	21.944	12.016	14.838
Foreign	Mean	18.432	8.536	10.708
	Std. Dev.	19.174	8.800	11.011
	Min	12.264	6.477	8.427
	Max	20.986	10.275	12.607

³ For comparison purpose we only report the efficiency results of industries where foreign affiliated firms operate. The results of the other industries are not given here to conserve space but available upon request from the corresponding author.

4. Empirical Results

In order to estimate technical efficiency and technology gap ratios using data envelopment analysis, we utilize the DEAP computer program developed by Coelli (1998). Average meta and group technical efficiency scores and technology gap ratios of domestic and foreign affiliated firms in the subsectors are reported in Table 2. To compare domestic and foreign affiliated subsectors also individually, the efficiency results of selected manufacturing subsectors are also presented in Table 3.

Table 2. Average Technical Efficiency and Technology Gap Ratios

	Average Technical Efficiency				Technology Gap Ratio	
	Domestic Firms		Foreign Affiliated Firms		Domestic Firms	Foreign Affiliated Firms
	Meta	Group	Meta	Group		
1992	0.8198	0.8503	0.8975	0.9258	0.9642	0.9695
1993	0.8263	0.8373	0.9320	0.9415	0.9869	0.9899
1994	0.8486	0.8752	0.9467	0.9469	0.9696	0.9997
1995	0.8252	0.8345	0.9316	0.9478	0.9888	0.9829
1996	0.8078	0.8234	0.9216	0.9300	0.9811	0.9910
1997	0.8019	0.8119	0.9000	0.9377	0.9877	0.9598
1998	0.8092	0.8144	0.8968	0.9282	0.9936	0.9662
1999	0.8274	0.8287	0.9082	0.9394	0.9985	0.9667
2000	0.8308	0.8308	0.9108	0.9428	1.0000	0.9661
2001	0.8087	0.8123	0.9024	0.9121	0.9955	0.9894
Average	0.8198	0.8503	0.8975	0.9258	0.9866	0.9781

As it is presented in Table 2, technical efficiency scores of each group (domestic and foreign affiliated firms in the subsectors) show a stable pattern over the period. Foreign affiliated firms are generally found to be more efficient in terms of both meta and group technical efficiency. The evidence on group-technical efficiency scores clearly implies the superiority of foreign affiliated firms and they produce approximately 92.6% of the maximum level of output under the given group technology set. Although meta-frontier technical efficiencies found to be less than those of the group technical efficiencies, they support the findings obtained from group frontiers. Meta-technical efficiencies suggest that foreign affiliated firms are able to produce 89.8% of their potential output under the meta-technology set.

Table 2 also reports the TGR's of foreign affiliated and domestic firms. In the first half of the analysis period, TGR's of the foreign affiliated firms are higher than those of domestic firms. However, domestic firms are closing the gap between the meta and group technology with the rise in TGR's especially after 1996 (see Fig. 2). When the whole period is taken into consideration, foreign affiliated firms have attained lower technology gap ratios. Firms operating in foreign affiliated subsectors, on average, produce only about 97.8% of the potential output given the available unrestricted meta-technology. However domestic firms are able to produce about 98.7% of their potential output.

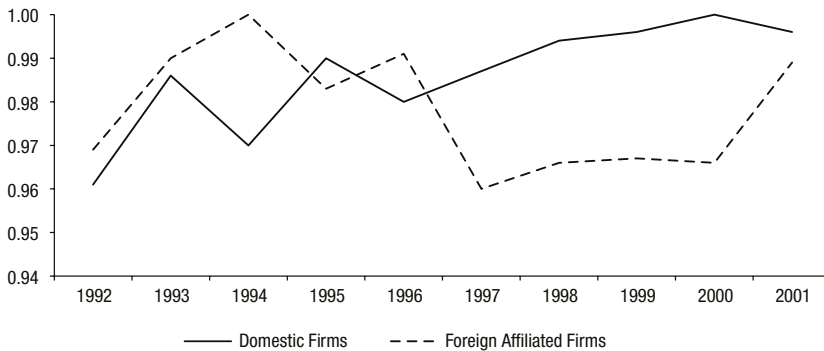


Fig. 2. Technology Gap Ratios of Domestic and Foreign Affiliated Firms

Individual technical efficiency scores with respect to group and meta-frontiers also confirm the superiority of foreign affiliated firms (see Table 3). Technical efficiency scores with respect to meta-frontier are ranging from 0.713 to 0.913 in domestic firms and they are less than those of foreign affiliated firms (see Table 3). Foreign affiliated firms operating in Tobacco (3140), Paints (3521), cleaning and cosmetics (3523) chemical (3529) and plastic products (3560) subsectors determine the meta-frontier at least in one year, i.e. the best input-output combinations are attained by these subsectors.

TGR's of the individual subsectors in Table 4 are also worth noting. The frontiers of domestic and foreign firms are tangent to the meta-frontier at least one time over the investigation period. Domestic firms operating in the tobacco industry have attained the highest TGR. This industry could produce about 99.9% of output that could be produced using the unrestricted meta-technology. The performance of this industry for foreign affiliated firms is found to be moderate. Although foreign affiliated firms have higher technology gap ratios in different subsectors, manufacture of paint, cleaning products, plastic and chemical products have attained the same TGR levels. However; the difference between domestic and foreign affiliated firms in terms of TGR's are less pronounced than those of meta-technical efficiencies. This evidence suggests that technological infrastructure may not be the main determinant in explaining productivity differences between domestic and foreign affiliated firms.

Table 3. Technical Efficiency Indicators of Selected Subsectors

	Technical Efficiency with respect to Group frontiers					Technical Efficiency with respect to Meta-frontiers										
	Foreign		Domestic			Foreign		Domestic								
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max				
3113	0.883	0.021	0.843	0.914	0.809	0.023	0.782	0.863	0.864	0.021	0.825	0.892	0.802	0.022	0.779	0.852
3140	0.982	0.018	0.958	1.000	0.846	0.036	0.8	0.894	0.941	0.039	0.88	1.000	0.845	0.036	0.8	0.893
3211	0.895	0.027	0.866	0.935	0.737	0.021	0.716	0.786	0.867	0.015	0.849	0.898	0.729	0.016	0.713	0.766
3521	0.967	0.031	0.922	1.000	0.905	0.033	0.845	0.956	0.963	0.031	0.922	1.000	0.885	0.022	0.839	0.913
3522	0.976	0.028	0.918	1.000	0.879	0.022	0.848	0.929	0.928	0.021	0.902	0.974	0.868	0.017	0.844	0.9
3523	0.992	0.014	0.965	1.000	0.899	0.023	0.865	0.944	0.983	0.015	0.965	1.000	0.884	0.019	0.855	0.905
3529	0.998	0.007	0.979	1.000	0.865	0.016	0.842	0.893	0.995	0.008	0.979	1.000	0.848	0.015	0.829	0.88
3560	0.931	0.051	0.869	1.000	0.797	0.024	0.765	0.845	0.928	0.052	0.869	1.000	0.784	0.016	0.761	0.817
3819	0.951	0.03	0.900	0.999	0.807	0.022	0.776	0.852	0.948	0.029	0.899	0.999	0.796	0.015	0.773	0.827
3829	0.923	0.023	0.883	0.944	0.825	0.017	0.807	0.859	0.882	0.021	0.865	0.935	0.815	0.011	0.803	0.837
3839	0.881	0.016	0.843	0.898	0.828	0.027	0.8	0.884	0.861	0.024	0.831	0.89	0.816	0.02	0.79	0.853
3843	0.847	0.021	0.798	0.869	0.787	0.018	0.758	0.812	0.818	0.017	0.786	0.847	0.775	0.012	0.755	0.792

3113: Canning and preserving of fruits and vegetables

3140: Tobacco manufactures

3211: Spinning, weaving and finishing textiles

3521: Manufacture of paints, varnishes and lacquers

3522: Manufacture of drugs and medicines

3523: Manufacture of soap and cleaning preparations, perfumes, cosmetics and other toilet preparations

3529: Manufacture of chemical products

3560: Manufacture of plastic products

3819: Manufacture of fabricated metal products except machinery and equipment

3829: Machinery and equipment except electrical

3839: Manufacture of electrical apparatus and supplies

3843: Manufacture of motor vehicles

Table 4. Technology Gap Ratios of Some Selected Subsectors

	Technology Gap Ratio							
	Foreign				Domestic			
	Mean	SD	Min	Max	Mean	SD	Min	Max
3113	0.978(10)	0.023	0.940	1.000	0.991(8)	0.008	0.973	1.000
3140	0.959(5)	0.027	0.911	1.000	0.999(5)	0.001	0.996	1.000
3211	0.970(9)	0.028	0.924	1.000	0.989(12)	0.010	0.971	1.000
3521	0.997(3)	0.008	0.975	1.000	0.979(1)	0.017	0.948	1.000
3522	0.952(6)	0.028	0.908	1.000	0.987(3)	0.012	0.968	1.000
3523	0.992 (2)	0.012	0.965	1.000	0.983(2)	0.017	0.953	1.000
3529	0.997(1)	0.006	0.985	1.000	0.980(4)	0.017	0.949	1.000
3560	0.997(7)	0.006	0.982	1.000	0.985(10)	0.013	0.962	1.000
3819	0.997(4)	0.006	0.981	1.000	0.987(9)	0.012	0.965	1.000
3829	0.956(8)	0.025	0.921	0.997	0.988(7)	0.011	0.965	1.000
3839	0.978 (11)	0.021	0.949	1.000	0.986(6)	0.013	0.963	1.000
3843	0.967(12)	0.018	0.951	1.000	0.986(11)	0.014	0.959	1.000

Note: The numbers in parentheses represent the ranking of subsectors with respect to meta-frontier technical efficiencies. See Table 3 for the classification numbers of the subsectors.

Table 4 also suggests that the domestic firms with high efficiency scores have attained relatively low technology gap ratios. This means that technically efficient firms are in fact using the low level of technology. The manufacture of paints containing the most efficient firms in terms of meta-technical efficiency has attained the lowest technology gap ratio. However, tobacco manufacturing ranked in the fifth place according to meta-technical efficiency has attained the highest technology gap ratio among the other subsectors. These evidences indicate the existence of a negative relationship between the TGR's and technical efficiency of the firms in domestic subsectors. However the results do not indicate any significant relationship between the technical efficiency and TGR's of foreign affiliated firms⁴.

5. Conclusions

This paper aims to compare technical efficiencies of the foreign affiliated and domestic firms in Turkish manufacturing subsectors by employing meta-frontier approach introduced by Battese and Rao (2002). This approach allows us to take into consideration the

⁴ In order to see the significance of the differences between TGR and TE of the domestic and foreign affiliated industries we conduct Spearman rank correlation tests. The correlation between TGR's and technical efficiency of the domestic industries indicates a highly negative relationship with -0.6848 and it is significant at 5 percent level. However the same statistic computed for the foreign affiliated industries are found to be insignificant.

heterogeneity in terms of technology level and helps us to construct a technology gap ratio to compare the relative efficiency levels of domestic and foreign affiliated firms.

We find that technical efficiency ratios of foreign affiliated firms are higher than domestic firms, and show a stable pattern during the period subject to the analysis. However, technology gap ratios of domestic firms show that domestic firms are closing the gap between the global technologies, especially after 1996. Unlike domestic firms, we see an opposite trend for foreign affiliated firms, of which the technology gap increases.

The meta-technical efficiencies and TGR's indicate the existence of a negative relationship between efficiency and gap ratios for domestic firms. However we do not find such a significant relationship for foreign affiliated firms. Low level of TGR in domestic firms can be attributed to low level of R&D and the absence of technology spillovers between domestic and foreign affiliated firms. These results confirm the previous findings that there is no horizontal FDI spillover to the domestic firms in Turkey (see Lenger, Taymaz 2006). The decline in TGR's observed in foreign affiliated firms can be also adhered to the fact that the amount of R&D expenditures of foreign affiliated firms has been declining in the recent years. According to TURKSTAT data, the total amount of R&D expenditures in manufacturing industries show an increasing trend until 1999, but nearly decreased by half in 2001 due to the financial crisis in November 2000–February 2001. When the shares of domestic and foreign affiliated firms are compared, except for 1998 domestic firms allocated more resources on R&D during the period subject to analysis (Karacuka, Catik 2011). UNCTAD (2005) also reports that Turkey is ranked as one of the least attractive countries in terms of R&D expenditures of TNCs, and the amount of R&D expenditures of foreign affiliated firms has been declining in the recent years. The absence of a significant relationship between TGR and technical efficiency in foreign affiliated firms should be investigated in more detail as the firm level data become available.

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