R&D ACTIVITY AND FINANCING CONSTRAINTS

Evidence from Turkey

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Abstract: We analyze the relationship between financing constraints and firms' R&D activity using a rich and comprehensive firm-level balance sheet and income statement data set of manufacturing firms in Turkey for the period 1996 to 2013. Using a firm-specific, time-varying financing constraints index, we find that financing constraints have a negative relationship with firms' R&D activity, after controlling for other determinants of R&D such as firm size, capital intensity and export market participation.

Keywords: R&D investment, financing constraint, credit constraint, internal funds, cash flow, Turkey

JEL classification codes: G30, G32, L20, O31, C33, E22

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1. Introduction

It is a widely-held view that the R&D activity is difficult to finance and highly susceptible to financing constraints. While a significant number of empirical studies find a negative relationship between financing constraints and R&D activity, Bronwyn Hall and Josh Lerner (2010) provide a comprehensive summary of the literature and conclude that it remains an open question whether financing constraints matter for R&D. We contribute to this empirical literature by providing an extensive empirical analysis of the link between R&D activity and financing constraints in the context of a developing economy, Turkey, for the period of 1996-2013. While there are studies on the determinants of the R&D activity by the Turkish firms, our analysis is a first with its specific focus on financing constraints. Turkey is a fitting case to examine this link, as the R&D expenditures of the private sector as a percentage of GDP remain around 0.92 by 2012, quite below the ratio for OECD countries (2.47%) or for upper middle-income countries (1.45%) (World Development Indicators 2016). We analyze the relationship between financing constraints and firms' R&D activity using a comprehensive firm-level data set based on the financial statements of manufacturing firms. In our analysis, we construct a firm-specific, time-varying index of financing constraints, and look at the impact of financing constraints on both the decision to start R&D activity and the level of R&D activity. Having controlled for firm size, capital intensity and export market participation, we find that financing constraints are negatively correlated with firms' R&D activity. We discuss the policy implications of our findings in the concluding section.

2. Literature overview

2.1 Financing constraints and R&D investment

There is a large literature studying the effects of financial factors on firms' investment decisions in the absence of perfect capital markets. Starting with Steven Fazzari, Glenn Hubbard and Bruce Petersen's (1988) seminal paper, the empirical literature has examined the links between financial variables and investment and found that financing constraints do matter for investment decisions. Financing constraints might be even more binding for R&D investment because of three main reasons (Hall and Lerner 2010). First, the problem of asymmetric information is more severe for R&D investment than for ordinary investment. Innovative projects are inherently complex and specific, making them difficult to be evaluated by outside investors. While managers are likely to have better information on their R&D project, given the nature of the innovative projects they may not want to reveal the details to outside investors and risk losing crucial information to their competitors (Dirk Czarnitzki, Hanna Hottenrott and Susanne Thorwarth 2011). Furthermore, R&D investment is inherently riskier than ordinary investments: the returns on R&D investment are highly uncertain and these investments have a low probability of success. As a result, lenders are likely to ask for a higher rate of return for R&D projects than they would ask from less risky investments in physical assets (Dirk Czarnitzki and Hanna Hottenrott 2011). Second, R&D investment creates intangible assets that are not easy to use as collateral for borrowing (Keenan P. Jarboe and Ian Ellis 2010). In the absence of other types of collaterals, this makes raising external funds for R&D investment costlier. Third, R&D activity involves sizeable fixed set-up costs and given the time it takes to succeed with a typical R&D project, these costs become sunk costs. For example, typically more than 50 percent of R&D expenditures are on wages and training of personnel (highly trained scientists, engineers etc.). Firing or re-hiring personnel and acquiring intangible assets require substantial expenditure and hence R&D activity may require continued financing. Given these high sunk cost and adjustment costs, a firm may decide to start new R&D programs only if it has (and is likely to continue having) sufficient resources to pursue the R&D activities from the very beginning of the project to its end. Furthermore, R&D investment is usually concentrated in firm-specific assets and cannot be resold in a secondary market during times of financial distress.

All in all, these characteristics of R&D activity may make it subject to credit rationing by potential lenders and as a result firms may constrain their R&D activity if they do not have enough internal resources to finance it. Firms that are financially constrained would have to limit their R&D activity to currently available funds and either postpone or abandon R&D projects that they would have invested in if they had funds available. As noted by Czarnitzki *et al.* (2011) this could lead to reduced incentives for long term R&D projects and may cause sub-optimal levels of R&D activity in the economy.

There is a growing empirical literature looking at the link between financing constraints and R&D activity. Hall and Lerner (2010) provide a review of this literature, which mostly focuses on the US and Western European economies. While the empirical evidence is not conclusive, a number of studies find a strong negative effect of financial frictions on innovation for the advanced economies. James Brown and Bruce Petersen 2009 studied US firms' investment-cash flow sensitivity and found a strong negative relationship between cash flow and R&D investment, interpreting this as sign of financing constraints. Similar results were found for France (Philippe Aghion, Philippe Askenazy, Nicolas Berman, Gilbert Cette and Laurent Eymard 2008), Germany (Hanna Hottenrott and Bettina Peters 2012), Portugal (Filipe Silva and Carlos Carreira 2012), S. Korea (Sanghoon Lee 2012) and transition economies (Yuriy Gorodnichenko and Monika Schnitzer 2013, Kadri Männasoo and Jaanika Meriküll 2014). In a recent study, Neil Lee, Neil, Hiba Sameen and Marc Cowling, Hiba Sameen and Marc Cowling (2015) found that there is a structural problem in the financial system that constrains finance for innovative firms with a sample of small- and medium-sized UK firms. Czarnitsky *et al.* (2011) look at the components of R&D and find that research investment is more sensitive to liquidity than development activity. Another line of research examines the links between financing constraints, R&D and exporting strategies. Juan Manez, Maria Rochina-Barrachina, Juan Sanchis-Llopis and Oscar Vicente (2014), for instance, find that internal and external financing constraints are relevant for the joint decision of export participation and investment in R&D for Spanish firms.

Research on the firm R&D activity in developing economies has been limited and the case of Turkey is not any different in that respect. The existing few studies on the R&D activity of firms in Turkey have mainly focused on other determinants of R&D, rather than financial factors. Among these Elif Kalaycı and Teoman Pamukçu (2014) analyzed the determinants of R&D investment in general; Emre Özçelik and Erol Taymaz (2008) and Vedat Tandoğan and Teoman Pamukçu (2011) examined the effect of public subsidies on R&D investment. As we use a different source of data, derived from firm-level balance sheets and income statements, we are able to conduct our analysis with a focus on financing constraints.

2.2 Measuring financing constraints

A central proposition of the literature is that if a firm is subject to financing constraints, then the availability of internal funds becomes a major determinant of its investment level and this logic applies to R&D activity, as R&D activity is seen as a form of investment. In empirical terms, this means including a cash flow variable into investment specifications as done by Fazzari et al. (1988). Since then, the use of investment-cash flow sensitivity has been criticized by many: Steven Kaplan and Luigi Zingales (1997) showed investment-cash flow sensitivities are not necessarily monotonic in the degree of financing constraints. Others argue that cash flow variable is closely related to operating profits, hence may be capturing the impact of expected profitability on investment, rather than liquidity effects. Following the criticism of the use of cash flow sensitivities as the measure of constraints, some studies utilized survey data, where firms are directly asked whether they are financially constrained (e.g. Thorsten Beck, Aslı Demirgüç-Kunt, Luc Laeven, and Vojislav Maksimovic 2006). While providing a direct measure, this approach has also been criticized for the subjective nature of self-assessed variables, as well as the difficulties of obtaining periodical survey data.

These works rely on a one-dimensional definition of financing constraint, assuming that a single variable can effectively identify the existence of a constraint. Furthermore, in most of these studies, firm characteristics such as size, age, dividend policy, membership in a group, existence of a bond rating, and concentration of ownership are used to determine *a priori* which firms are financially constrained. Such criteria tend to be time invariant, whereas firms may switch between being constrained or unconstrained depending on the overall credit conditions, investment opportunities and idiosyncratic shocks.

An alternative measure is a class-ranking index, first introduced by Patrick Musso and Stefano Schiavo (2008) and later adopted by Flora Bellone, Patrick Musso, Lionel Nesta and Stefano Schiavo (2010). Here, firms in a certain class (e.g. industry or region), which are believed to be relatively homogenous, are ranked based on several variables that are found to have a relationship with financing constraints. For each variable, the relative position of each firm to the corresponding class average is computed and firms are ranked based on this relative position. Then rankings from all variables are combined into a single score of financing constraints. In this study, we adopt this approach and combine information coming from four different variables, which are selected on the basis of their perceived importance in determining ease of access to external funds: firm size, profitability, liquidity, and solvency ratio. Firm size is based on total assets; profitability is measured as return on total assets (ROA); liquidity is the ratio of current assets to current liabilities; and solvency is the ratio of equity to total liabilities. According to NACE.2 rules (*Nomenclature statistique des Activités économiques dans la Communauté Européenne* - Statistical classification of economic activities in the European Community), manufacturing firms are classified under the industry categories of C10 through C33 and based on this classification we have firms belonging to 23 manufacturing industries in our data set. For each of the four dimensions mentioned above and for each year, we first compute the 2-digit NACE industry averages. Then we divide each firm's observation for a particular dimension in one year by that year's industry average for the industry that the firm belongs. By scaling each firm/year observation by the industry average, we account for industry-specific differences in these financial variables. Based on the distribution of these scaled values within each year, we assign a number to each firm, ranging from one to five, depending on the quintile the firm observation corresponds to. Hence, for each firm/year observation we end up with four scores ranging from one to five. Finally, we add up these four scores and obtain an index that ranges from 4 to 20. Firms with low scores are expected to be the most financially constrained, and as the index number goes up, we expect financing constraints to be eased. A positive link between R&D and this index value implies that firms with higher index values face lower credit constraints, which, in turn, allows them to have higher R&D levels.

2.3 Modeling the determinants of R&D investment

Given the theoretical framework and the empirical literature, we pose a standard R&D investment demand function to analyze the relationship between financing constraints and R&D investment:

$$R\&D_{it} = \alpha + \beta Score_{it} + \delta X_{it} + u_{it} \qquad (1)$$

where *R&D* is real R&D expenditures expressed in 1,000 Turkish liras adjusted for inflation**,** α is a constant term, *SCORE* is an indicator of the firm's financing constraint and *X* is a vector of determinants of R&D investment. *i* denotes firm and *t* denotes time. β is the responsiveness of real R&D expenditures to credit score and δ is a set of coefficients that represents the responsiveness of real R&D expenditures to the vector of control variables. The financing constraint variable, *Score*, is constructed as a firm-specific, time-varying index, as described above. The control variables (in the X vector) include firm size, capital intensity, export ratio, and industry dummies. Firm size is considered to be important as large firms can carry out R&D activities in a variety of fields and unexpected research results in one field can feed research in another field (Joseph Schumpeter 1942). They have large internal funds to use in the financing of uncertain and risky R&D activities and have better access to external financing. Furthermore, it is more likely for small- and medium-sized firms to be risk averse and avoid R&D investment which is typically highly risky and uncertain. Schumpeter (1942) had defined two types of innovative regimes: Mark 1: entrepreneurial regimes dominated by small innovative firms (creative destruction) and Mark 2: environments where innovations are generated and implemented by large established firms (creative accumulation). In this context, it is also possible for firm size to have a negative impact on R&D as bureaucratic barriers impeding circulation of information within firms, risk-adverse management etc. can hinder R&D investment. Yet, in the empirical literature a positive relationship is observed between firm size and R&D investment. The next control variable we employ is capital intensity. Sergio Kannebley and Julia Valeri Sekkel (2010) argue that especially in developing economies, capital intensity can be a form of embodied technological transfer from advanced economies. Export orientation is another variable that may contribute to R&D investment. Export market participation may impact R&D as it may expose firms to intense competition where they may need R&D investment in order to meet the strict cost and/or product specification costs (Keller 2010). It is also possible that firms gain from technology or information transfer provided by foreign markets through product standards. Yuriy Gorodnichenko and Monika Schnitzer (2013), with a focus mostly on developing countries, argue that innovation and export activity are complementary for financially healthier firms. Finally, we consider market structure as a possible determinant of R&D activity. The link between R&D and market structure can be conceptualized as a matter of degree of competition a la Schumpeter, or industry level knowledge spillovers. To capture these possible effects, we include industry dummies among our control variables.

3. Data, variables, and descriptive statistics

We use the *Company Accounts* data set, which covers the period between 1996 and 2013. The data set is compiled by the Central Bank of the Republic of Turkey, and not available for public distribution due to confidentiality issues. However, researchers can access the data set on site at the Bank. This is the most comprehensive source of firm-level annual balance sheet and income statement data on nonfinancial firms in Turkey. The data set is well-suited to the study of financing constraints as it includes the firms in the economy that have accounts with the banking system (CBRT *Methodological Information*). We focus on manufacturing firms (NACE.2, industry categories C10-C33) that represent the largest portion of employment and total assets in the data set and constitute a sample with continuous reporting of financial statements. At the end of 2013, our data set includes around 4,000 manufacturing firms, which make up approximately 54 percent of total manufacturing sales and 27 percent of total manufacturing employment in the economy (Annual Industry and Service Statistics by the Turkish Statistical Institute). Exclusion of diverse sectors under industry, such as mining and agriculture, as well as services helps keep the firm heterogeneity in the sample under control. For example, both the effect and the severity of financing constraints on innovation may vary across firms in manufacturing and services. The combination and use of innovation inputs can differ substantially, too. The lesser need for R&D and stronger role of other inputs in services implies that the impact may be less pronounced in services than in manufacturing.

Table 1: Number of firms and the median values of their key statistics in 2013

	Low-tech firms	Medium-low-tech firms	Medium-high-tech firms	High-tech firms
Number of firms	1474	916	564	51
R&D expenditures as a percentage of sales	0.28	0.35	0.64	1.06
Number of employees	97	88	97	96
Capital intensity	23,961.6	33,477.1	26,780.1	24,616.6
Exports as a percentage of sales	4.2	6.1	1.1	1.7
Credit Score	11	12	12	9

A common problem with firm-level data is the existence of large outliers. Following common procedure in the literature, we clean the outliers by excluding 1% from both ends of *total assets* and *net sales*. The final sample is an unbalanced panel of 8,559 firms over 18 years. Table 1 presents an overview of key ratios in 2013, which is the last year of observations in our sample. Here, we use the classification method used by the Eurostat to aggregate manufacturing industries according to their technological intensity. With this system, based on NACE Rev.2. at 2-digit level, industries are categorized as high-technology, medium high-technology, medium low-technology and low-technology. In terms of the number of firms, we observe that the majority of the firms in our sample are in low-tech and medium-tech industries. What is interesting about these firms is their relatively higher export ratios. The median value of number of employees in each category is very close to each other, with the exception of medium-low-tech firms. A similar distribution is also observed for the capital intensity of these firms.

4. Empirical analysis

Our sample includes both R&D performers and non-performers. In section 4.1 we first divide our sample into R&D performers and non-performers and look at the determinants of the decision to start R&D activity through logit analysis. Section 4.2 presents the results of the Tobit and Wooldridge Tobit analyses for the whole sample. While the Tobit analysis gives us a general idea in terms of the relationship between financing constraints and R&D activity, it suffers from the problem of imposing the restriction that the effects of explanatory variables on the changes in the level of R&D expenditures and on the decision to (or not to) invest in R&D are equal up to a constant of proportionality. Hence, we use Wooldridge Tobit to address this issue. In section 4.3 we focus only on the R&D performers and look at the determinants of the level of R&D activity. We use the statistical software package Stata 14 to conduct our analyses.

We start with an expanded econometric specification of the standard R&D investment demand function of equation 1:

$$R\&D_{it} = \alpha + \beta Score_{it} + \delta X_{it} + \eta_i + ð_j + \gamma_t + \varepsilon_{it} \qquad \textbf{(2)}$$

where $R\&D_{it}$ is real R&D expenditures and $Score_{it}$ is an index of financing constraints. The coefficient of interest for us here is β. X_{it} includes control variables size, capital intensity and export ratio. α is the constant term; $ð_j$ is an industry dummy; η_i is a time invariant firm fixed effect; and γ_t represents time fixed effects. R&D is the log of real R&D

expenditure; size is defined by log number of employees; capital intensity is the log of real capital stock per employee, where capital stock is computed as tangible fixed assets net of depreciation and land. Finally, export ratio is the share of foreign sales in net sales. Manufacturing price index is used to convert nominal values to real values. This equation implies that if firm-specific fixed effects are accounted for, R&D investment can be used as the dependent variable in the R&D demand function. In this model, a potential simultaneity bias could arise when there are feedback effects from the dependent variable to current explanatory variables. While a distributed lag model could potentially address simultaneity bias, we use only one lagged value of all time-variant variables mainly due to two reasons: 1) in our unbalanced panel data, there is a great variation in the length distribution for firms; 2) firm-level explanatory variables derived from balance sheets are likely to be autocorrelated, a condition that would cause multicollinearity in a distributed lag model. Specifically, we estimate the following specification:

$$R\&D_{it} = \alpha + \beta_1 \, Size_{it-1} + \beta_2 \, (K/L)_{it-1} + \beta_3 \, Export_{it-1} + \beta_4 \, Score_{it-1} + \eta_i + ð_j + \gamma_t + \varepsilon_{it} \quad \textbf{(3)}$$

We include firms with at least four consecutive years of observations in our sample for the analysis. Before moving onto the estimations some descriptive statistics are in order. Table 2 displays descriptive statistics for the regression variables for firms both with and without R&D expenditures. A cursory look at Table 2 suggests that firms with R&D expenditures are in general larger in size, have higher export ratios, higher capital intensity, and lower financing constraints.

Table 2: Descriptive statistics

R&D expenditure=0					
	Median	Mean	Standard deviation	n	N
Number of employees	80	164.7	265.3	5656	45654
Capital intensity	17,319.6	46064.9	24,3779.9	5656	45654
Export ratio	0.08	0.24	0.31	5656	45654
Credit Score	12	11.9	3.4	5656	45654
R&D expenditure>0					
	Median	Mean	Standard deviation	n	N
Number of employees	186	355.8	535.3	1935	9498
Capital intensity	24,659.49	45,250.44	93,427.72	1935	9498
Export ratio	0.16	0.26	0.27	1935	9498
Credit Score	13	13.1	3.5	1935	9498

Note: Includes firms with 4 consecutive years of observations after outlier cleaning.

4.1 Decision to start R&D: Logit estimations

In this section we employ a logit model to test the determinants of the decision to (or not to) invest in R&D. To that end, we define our dependent variable in Equation 3 as a binary variable that takes the value of 1 if the firm is an R&D performer and 0 if not and estimate it using both fixed effects logit and random effects logit models. Based on a comparison of these two models, we then check whether the individual unobservable firm effects should be treated as fixed or random. The results of this exercise are presented in Table 3. Note that the number of observations in the fixed effects logit model is lower because the fixed effects model is estimated only for those firms that changed their R&D

status. We employ the Hausman specification test, reported at the bottom of the table, to compare the two estimations and reject the null hypothesis that regressors are unrelated to firm fixed effect. Therefore, fixed effects estimator seems to be a better fit for our sample, when R&D choice is the dependent variable. Both estimations give statistically significant results for the credit score variable as well as the control variables size, capital intensity and export ratio. The significantly positive coefficient for credit score suggests that the decision to perform R&D or not is negatively affected by financing constraints.

Table 3: Logit estimations

Dependent variable: R&D decision (1 for R&D performers, 0 for non-performers)		
	Fixed effect logit	**Random effect logit**
Size	0.431***	0.821***
	(0.05)	(0.037)
Capital output ratio	0.159***	0.316***
	(0.033)	(0.028)
Export ratio	0.303*	0.128
	(0.159)	(0.126)
Credit score	0.025***	0.042***
	(0.009)	(0.008)
# of firms	1,463	5,987
# of observations	15,162	49,131
Overall significance	LR chi2(20)= 299.17***	Wald chi2(20)= 739.40***
Hausman test (Ho: difference in coefficients is not systematic)	chi2(20) = 173.21***	

Notes: (i) Regressions are estimated for firms with at least 4 consecutive years of observations. (ii) Standard errors are reported in parentheses. (iii) Time dummies and a constant are included in both regressions. (iv) *** p<0.01, ** p<0.05, * p<0.1

4.2 Determinants of R&D: Tobit estimations

The use of random effects Tobit model to estimate the R&D investment demand function allows the use of data for R&D performers and non-performers together. We start with a random effects Tobit model to estimate Equation 3 and present the results in the first column of Table 4. Our coefficient of interest, the credit score variable has a positive and statistically significant relationship with R&D expenditures, indicating the importance of financing constraints for R&D expenditures. As the score increases, indicating a relaxing of financing constraints, R&D expenditures increase too. Our control variables all have the expected signs: coefficients of size, capital intensity and export ratio are positive and statistically significant.

Table 4: Tobit and Wooldridge Tobit estimations

Dependent variable: log (real R&D expenditures)		
	Tobit	**Wooldridge Tobit**
Size	0.602***	0.357***
	(0.022)	(0.027)
Capital output ratio	0.193***	0.110***
	(0.016)	(0.018)

Export ratio	0.180**	0.143
	(0.077)	(0.088)
Credit Score	0.029***	0.017***
	(0.005)	(0.005)
# of firms	5,987	5,987
# of observations	49,131	49,131
Overall significance	Wald chi2(43)=2057.16***	Wald chi2(47)=2371.14***
Joint significance of within means		chi2(4) = 72.18***
Joint significance of year dummies	chi2(16) = 184.84***	chi2(16) = 246.21***
Joint significance of industry dummies	chi2(23) = 772.47***	chi2(23) = 821.26***

Notes: (i) Regressions are estimated for firms with at least 4 consecutive years of observations. (ii) Standard errors are reported in parentheses. (iii) Time dummies and a constant are included in both regressions. (iv) *** p<0.01, ** p<0.05, * p<0.1

A potential issue with the Tobit model is that it imposes the restriction that the effects of explanatory variables on the changes in the level of R&D expenditures and on the decision to (or not to) invest in R&D are equal up to a constant of proportionality. In more technical terms, the crucial issue in the estimation is the unobserved firm level heterogeneity, η_i in Equation 3, and its correlation with the covariates. The Tobit model assumes that there is no correlation between X_{it} and η_i. To address this issue, we use a 'fixed effects' approach, which treats the heterogeneity as parameters to be estimated. In the next step, we relax the assumption of no correlation between X_{it} and η_i by modifying the Tobit model as suggested by Jeffrey Wooldridge (2002) in the spirit of Yair Mundlak (1978) restriction. We add over-time averages (within means) of variables in the X_{it} as regressors:

$$R\&D_{it} = \alpha + \beta X_{it} + \zeta \overline{X}_i + \lambda_i + \eth_j + \gamma_t + \varepsilon_{it} \quad \textbf{(4)}$$

where $\eta_i = \zeta \overline{X}_i + \lambda_i$

The appropriateness of the Wooldridge model will be tested by the joint significance of the x-variables' 'within' means (null hypothesis that $H_0 : \zeta = 0$). The results from the Wooldridge Tobit estimator are presented in the second column of Table 4. The first thing to note is that the hypothesis that X_i and firm heterogeneity are uncorrelated is rejected, meaning regardless of the source of correlation, the Wooldridge Tobit model should be used for interpretation. Yet, the estimation results from the Wooldridge Tobit model and the regular Tobit model are very similar in terms of the statistical significance of the coefficients with the exception of the export ratio. The coefficient of the credit score still has a positive and statistically significant relationship with R&D expenditures

4.3 Continuous R&D performers: Fixed effects and GMM estimations

In the next step, we focus on firms that undertake continuous R&D investment and examine the effect of financing constraints on the level of R&D expenditures. Having rejected the null hypothesis of the consistency of a random effects model, based on a Hausman test, we choose to conduct this analysis relying on a fixed effects model. It should be noted that the results from both models are qualitatively the same in terms of statistical significance and the signs of the estimated coefficients. We report here only the results for the fixed effects model. Since we only use firms with continuous R&D expenditures over years, the number of firms and observations go down significantly for this model.

Results of this estimation are presented in Table 5. We observe that as the financing constraints are eased, the level of R&D expenditures increases.

Table 5: Fixed effects and GMM estimations with R&D performers only

Dependent variable: log (real R&D expenditures)		
	Robust fixed effects	**System GMM**
Size	0.618***	0.361***
	(0.084)	(0.119)
Capital output ratio	0.136**	0.099
	(0.063)	(0.096)
Export ratio	-0.245	-0.194
	(0.291)	(0.285)
SCORE	0.0201**	0.0260***
	(0.009)	(0.010)
$R\&D_{t-1}$		0.587***
		(0.064)
$R\&D_{t-2}$		0.107**
		(0.044)
# of firms	331	273
# of observations	2845	2388
Overall significance	F(20,330)=9.26***	Wald chi2(21) = 367.12 ***
Joint significance of year dummies	F(16, 330) =6.82***	chi2(15) = 56.69***
AR(1)		z = -4.90 Pr > z = 0.000
AR(2)		z = 0.19 Pr > z = 0.853
Sargan Test of overidentifying restrictions		chi2(67)=69.42 Prob > chi2 = 0.396
Hansen Test		chi2(67)= 68.21 Prob > chi2 = 0.436

Notes: (i) Fixed effects regression is estimated for firms with at least 4 consecutive years of observations and GMM for firms with at least 5 consecutive years of observations. (ii) Robust standard errors in parentheses. (iii) Time dummies, and constant are included in both regressions. (iv) *** p<0.01, ** p<0.05, * p<0.1 (v) GMM estimates are obtained by the two-step system GMM using Stata.

An alternative framework that tackles with the issues originating from fixed effects is the use of a difference estimator, which would also allow us to explore the dynamic adjustment process of R&D. R&D performing firms tend to smooth their R&D investment over time as R&D has high adjustment costs due to the high cost of temporary hiring and firing of highly skilled employees with firm-specific knowledge as discussed above. To capture this partial adjustment process, we include lagged R&D values in our specification. Inclusion of lagged R&D causes potential endogeneity problems and requires an instrumental variables estimator. We use a system GMM approach for this purpose and present the results in Table 5. It should be noted that we first estimate a system GMM model for the specification with first lag of R&D as independent variable. This specification fails the autocorrelation test and hence is not valid. To address this problem, we include the second lag of R&D in the regression, as commonly practiced in dynamic panel data models. In this model, all firm-level explanatory variables, including the lags of R&D expenditures are treated as endogenous and instrumented by the second and farther lags of these variables. The instrument matrix is collapsed to prevent instrument proliferation. Only firms with at least 5 consecutive years of observations are included in the analysis.

The positive and statistically significant coefficients of the lagged R&D variables indicate that there is a partial adjustment process in R&D activities as they are multi-year, path-dependent projects. In this specification, too, the coefficient of the credit score variable is positively correlated with R&D expenditures and is statistically significant. All control variables still have coefficients with the expected signs and the financing constraint variable is also statistically significant.

5. Summary and concluding remarks

R&D investment has long been considered as a main driver of economic growth and a large theoretical and empirical literature exists on the determinants of R&D investment. More recently, empirical literature has looked at the effect of financial factors on R&D expenditures. This literature is mostly focused on advanced economies. In this paper, using a rich firm-level data set, we have examined the link between financing constraints and R&D expenditures for Turkey, a major developing economy. Our paper is the first study looking at this relationship for Turkish firms and is among the few studies that examine this relationship in the context of developing countries. Our main interest was the effect of financing constraints on R&D expenditures. We examined this link both in the context of the decision to perform and the level of R&D and constructed a credit score index to proxy for financing constraints. The results of the fixed effects and random effects logit estimations showed that the decision to invest in R&D is positively affected by the credit score variable indicating the role of financing constraints faced by the firms. When we used a random effects Tobit model as well as a Wooldridge Tobit model we again found that our credit score variable has a statistically significant and positive coefficient. Finally, we focused on a sub-sample of firms with continuous R&D expenditures and the results of our fixed effects and GMM estimations showed the same positive correlation between the credit score variable and the level of R&D expenditures.

Our finding in terms of the negative effect of financing constraints on both decision to undertake R&D and the intensity of R&D is in line with the suggestions that markets are unlikely to provide sufficient research, leading to suboptimal levels of R&D activity. Suboptimal levels of R&D investment create losses for the whole economy. A straightforward implication of this finding would be that public policy and intervention may be needed to increase R&D activity (Ari Hytinen and Otto Toivanen 2005) including loan guarantees, subsidies as well as direct public investment in R&D activities. An important area for future research would be to examine the effectiveness of public support for R&D activities in this context.

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Appendix 1: Technological intensity classification

High-technology:

- Manufacture of basic pharmaceutical products and pharmaceutical preparations (21);
- Manufacture of computer, electronic and optical products (26)

Medium-high-technology:

- Manufacture of chemicals and chemical products (20);
- Manufacture of electrical equipment (27);
- Manufacture of machinery and equipment n.e.c. (28);
- Manufacture of motor vehicles, trailers and semi-trailers (29);
- Manufacture of other transport equipment (30)

Medium-low-technology:

- Manufacture of coke and refined petroleum products (19);
- Manufacture of rubber and plastic products (22);
- Manufacture of other non-metallic mineral products (23);
- Manufacture of basic metals (24);
- Manufacture of fabricated metal products, except machinery and equipment (25)
- Repair and installation of machinery and equipment (33)

Low-technology:

- Manufacture of food products (10);
- Manufacture of beverages (11);
- Manufacture of tobacco products (12);
- Manufacture of textiles (13);
- Manufacture of wearing apparel (14);
- Manufacture of leather and related products (15);
- Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials (16);
- Manufacture of paper and paper products (17);
- Printing and reproduction of recorded media (18)
- Manufacture of furniture (31);
- Other manufacturing (32)