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Abstract

Using firm-level data from 2007 to 2016 for 116 R&D companies located in Romania, the main purpose of this paper is to compute the TFP and to see to what extent the productivity level is influenced by the financial performances and the corporate governance of these firms. To this end, we use several metrics for the TFP computation, relying on Wooldridge (2009), Levinsohn and Petrin (2003), OLS residuals and fixed effect model residuals. Our bootstrap panel quantiles regressions show that firm size and profitability are important for increasing the overall productivity of R&D companies, while the structure of investment and the taxation have no significant effect. In addition, the presence of foreign ownership generates a higher productivity. However, the degree of independence in making decision, and the ownership involvement in the firms' management, have a negative impact on TFP. While the presence of women on board is important for low-productivity firms only, curiously, the state-owned applied research institutes record a higher productivity compared with the R&D private firms. These findings are robust to different approaches used for the TFP computation, and to the number of iterations used for the confidence intervals.

Keywords: productivity; R&D sector; corporate finance and governance; panel quantiles regression; Romania

JEL Classification: D24, O30, G32, C33

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1. Introduction

Firms' efficiency is very important for the general economic welfare. One way to assess the firms' overall efficiency is represented by the computation of the Total Factor Productivity (TFP), considered as the main driver of economic growth in the long run (Easterly and Levine, 2001).[1] The purpose of this paper is to assess the TFP for companies activating in the research and development (R&D) sector in Romania, and to assess its determinants, with a focus on firms' financial performances and corporate governance.

A first book of the literature considers firms' financial performances, financial structure and the innovation capacity as key drivers of productivity level. First, the literature highlights the positive role of intangible assets (a *proxy* of R&D activities) in influencing the level of firms' productivity. After the pioneering studies by Griliches (1958) and Minasian (1969), the policy makers and researchers manifested an increased interest for the R&D investment and its role in enhancing the social return and firms' efficiency (for a review of the literature, please refer to Ugur et al., 2016). Recent works in this are investigate the non-linear linkages between R&D and productivity growth (e.g. Kancs and Siliverstovs, 2016). At the same time, the role of Information and Communication Technology (ICT) capital is put forward by Oliner and Sichel (2003), Ilmakunnas and Miyakoshi (2013) and Venturini (2015). Second, the corporate finance literature shows that there is an equilibrium between the level of intangible assets and the firms' financial structure. In this line, empirical results show a negative relationship between leverage and productivity (Nucci et al., 2005). Third, both firms' financial performances in terms of profitability, and the firms' size, have direct benefits for the productivity level (Yu et al., 2017). Finally, the fiscal aspects are put forward to explain the productivity at the firm level (Arnold et al., 2011; Bournakis and Mallick, 2018).

A second book of the literature investigate the role of corporate governance in influencing the firms' efficiency and productivity level (Chiang and Lin, 2007; Gaitán et al., 2018). One strand of literature underlines the role of ownership diversification and examines its impact on productivity (Schoar, 2002; Dimelis and Papaioannou, 2016). Another strand of literature focus on the role of gender diversity in the board, in influencing firms' efficiency (Bardasi et al., 2011; Marques, 2015). Finally, the most consistent strand of literature

[1] Another competing measure of firms' efficiency is the Tobin's Q. However, compared with this ratio, the TFP measure of efficiency is relatively uncorrupted by the choice of accounting methods (Hill and Snell, 1989). Further, the TFP allows for different factor intensities in different firms and industries (Schoar, 2002).

investigates the role of foreign ownership and foreign direct investment (FDI) on firms' productivity. Foreign firms are involved in the diffusion of new technologies and R&D spillovers (Savvides and Zachariadis, 2005; Coe et al., 2009; Liao et al., 2009; Kukulski and Ryan, 2011). At the same time, the sectoral innovation and location are important for enhancing the productivity level (Aiello et al., 2014, 2015).

Our contribution to the existing literature is fourfold. First, different from previous studies we compute the TFP for the companies activating in the scientific research and development sector (NACE code 72) from Romania. As far as we know, this is the first paper addressing the firms' efficiency in terms of productivity, with a focus on the research and development sector. Consequently, our primary interest is on the productivity determinants of innovation producers, and not on R&D spillovers. Further, Romania is an interesting case study given its communist past, where the presence of state-owned companies in a poorly developed R&D sector is very high.

Second, we merge the bulks of literature exposed above and we focus on two categories of productivity drivers, namely the firms' financial performances and financial structure, and corporate governance. On the one hand, we empirically investigate the role of intangible to total fixed asset ratio, profit margin and taxation level on TFP. We also control for the firms 'size effect. On the other hand, we assess the role of ownership structure, board diversity, shareholder-managers and independence in taking decisions on enhancing the productivity level. A special emphasis is placed on the role of firm-level FDI in explaining the TFP.

Third, we use different approaches to compute the TFP, for robustness purpose. We adopt a classic approach and regress the output (i.e. firms' added value) on the factors considered to be linked with the changes in the productivity level (labor and capital). Likewise, we compute the TFP using an Ordinary Least Square (OLS) and a fixed effects model (similar to Liao et al., 2009). At the same time, like Boeing et al. (2016), we control for different productivity shocks across firms, and we resort to the Levinsohn and Petrin's (2003) approach. Finally, we use contemporaneous and lagged state variables as instruments for a General Method of Moments (GMM) approach (following Wooldridge, 2009).

Fourth, our contribution is methodological. Different from previous empirical works relying on GMM models, we use bootstrap panel quantiles regressions. The quantile regression allows us to consider the heterogeneity in terms of TFP level, and it was recently used by (Di Cintio et al., 2017). Firms' financial performances and especially the corporate governance elements might have a different impact on low-productivity, compared with high-productivity firms. However, assessing the accuracy of each quantile parametric regression estimate and therefore the identification of an adequate asymptotic variance-covariance matrix is problematic. Therefore, we resort to a bootstrap resampling approach to compute the confidence intervals. At the same time, we use a different number of iterations for robustness purpose.

The rest of the paper is as follows. Section 2 presents the literature review on TFP determinants. Section 3 briefly presents the R&D sector from Romania. Section 4 describes data and methodology. While in section 5 we report the main empirical findings, section 6 is dedicated to a robustness analysis. The last section concludes and draws the policy implications of our study.

2. Determinants of TFP: literature review

The drivers of TFP are related to the R&D capital, ICT capital, human capital and organizational capital (van Ark, 2004). These inputs might be roughly associated with the managerial performance, either reflected by the firms' assets and their financial structure, or by the way the managers interreacts with firms' shareholders in the decision-making process.

Consequently, firms' financial performances and the innovation capacity, as well as their financial structure, stands for a distinctive category of efficiency drivers. First, the R&D activities and their impact on productivity are put forward by Minasian (1969). In this line, Dabla-Norris et al. (2012) underline the positive role of innovation for productivity, while the effect being larger in less-developed countries, and for high-tech firms. However, although the theoretical background describing the R&D-productivity nexus is well setup, the empirical results shows that this relationship is not straightforward. On the one hand, the recent work by Kancs and Siliverstovs (2016), who employ firm-level data for OECD countries, shows that the relationship between R&D expenditures and productivity growth is non-linear. On the other hand, the literature review made by Ugur et al. (2016) underlines that the R&D influence on firms' efficiency is relatively small.

Second, and related to the first strand of literature, the level of intangible assets (a proxy for R&D investment), is connected to firms' financial structure, as more innovative firms tend to have a different capital structure compared with less innovative ones (Nucci et al., 2005). Apparently, firms' leverage is negatively correlated with their capacity to innovate, and therefore, firms' leverage negatively impact their productivity. Likewise, Ferrando and Ruggieri (2018) discover for a set of firms that general financial constraints negatively impact the TFP over the timespan 2005 to 2011. Similar, Chen and Guariglia (2013) show for a panel of 130,840 Chinese manufacturing firms over the period 2001 to 2007 that financial constrains influence the productivity, especially for foreign and private firms.

Third, a series of other elements affecting the firms' performances are put forward by the empirical literature. On the one hand, for a set of Chinese manufacturing firm over the period 1998 to 2007, Yu et al. (2017) show that both firms' size and profitability are related to the productivity level. On the other hand, the fiscal aspects are found responsible for influencing the corporate TFP. In this line, Bournakis and Mallick (2018) state the that a higher level of profit tax induces distortive effects on productivity growth, given its impact on R&D activities (Hall and Van Reenen, 2000) and on the cost of capital (Devereux and Griffith, 2003). Using an unbalanced panel data of 7,400 manufacturing firms in the UK during 2004–2011, the authors report that corporate tax adversely affects TFP growth. Similar, with a focus on 20 US manufacturing industries, Minniti and Venturini (2017) find evidence that a friendly tax treatment of R&D activities positively impacts the growth of TFP.

The second bulk of the literature deals with the relationship between corporate governance and productivity (for a recent review of the literature, see Kong and Kong, 2017). A first set of papers analyze the role of board size, board diversity and independence of decision-making process, in enhancing TFP. Likewise, for a sample of 670 firms over the timespan 2006 to 2014, Gaitán et al. (2018) find that all these elements influence affect firms' productivity, while the relationship between board size and productivity is nonlinear. Several works (e.g. Schoar, 2002; Maeques, 2002) underline the role of board diversity, and the role of women on board, in increasing firms' efficacy, including the level of productivity. The presence of women on board characterizes the board diversity and ensure an equilibrium in the decisional process. In addition, independent directors can contribute to an increase productivity level in the case of an effective corporate governance and absence of managerial myopia. In this line, Jiraporn et al (2018) show that board independence leads to significantly higher innovation productivity. Finally, in connection with the later element, the role of Chief Executive Officer (CEO) duality is investigating by the literature. According to the agency cost theory (Jensen and Meckling, 1976), firms' performances may decrease if the CEO simultaneously serves as the chair of the board. Conversely, the organization theory (Donaldson and Davis, 1991) argue that a single command leads to an unambiguous leadership, which increases the firms' performances. Chiang and Lin (2007) test these opposite theories for a set of 232 Taiwan manufacturing firms and show that CEO duality is able to improve productivity.

The second set of researches focuses on the role of ownership structure in enhancing firms' productivity. In this line, Chiang and Lin (2007) show that the ownership structure in a firm affects the differences in terms TFP between various categories of firms. With a focus on listed Chinese firms for the period 2001 to 2011, Boeing et al. (2016) argue that private owns firms obtain better performances and generate higher TFP. This result confirms the previous findings reported by Jefferson et al. (2000), who argue that TFP growth in the Chinese domestic non-state sector is above the average. Similar findings are reported by Bastos et al. (2014) for Portuguese firms from 1991 to 2009, and by González-Páramo and Hernández De Cos (2005) for the Spanish case. However, conducting an industry-level research for South European countries, Dimelis and Papaioannou (2016) report a nonsignificant role of the private ownership in enhancing TFP.

A special attention is paid to the role of foreign ownership and FDI in influencing the TFP. Multinational enterprises may bring knowhow transfer, world-wide reputation and can realize economies of scale. Several papers underline the impact of technology diffusion (Griffith et al., 2004; Savvides and Zachariadis, 2005), and positive FDI spillovers (Pfaffermayr, 1999; Xu, 2000). Likewise, the impact of FDI spillover on TFP for 1,328 firms from Cina's electronic industry, over the period 2003 to 2008, is investigated by Liu et al. (2016). On the one hand, the authors show that the impact of FDI on TFP is influenced by the productivity gap. On the other hand, the foreign ownership enhances the technological transfer, and therefore, the TFP. With a focus on Indian manufacturing sector, Khachoo et al. (2018) report similar findings. However, although the impact of FDI on productivity is positive, firms' location matters and incumbents near the frontier receive higher benefits. Harris and Moffat (2015) conduct an analysis on the determinants of TFP in UK over the period 1997 to 2008. As novelty, they report that the age of the firm is negatively correlated with the TFP. At the same time, the foreign ownership is found to be the least important determinant. A different research is performed by Ashraf et al. (2016), who investigate the effects of greenfield FDI on TFP at 'macro' level. The authors use a dynamic panel data model and, in contrast with other papers, find that greenfield FDI has no statistically significant effect on TFP.

To the best of our knowledge, none of the previous papers combines the two bulks of the literature described above. We fill in this gap and we focus on both categories of TFP drivers. On the one hand, we consider the firms' financial performances, firms' size and its innovation capacity. On the other hand, we investigate the role of corporate governance in enhancing the TFP level. In addition, while most of previous works focus on the manufacturing sector, our interest is on the R&D industry from Romania.

3. A short presentation of the Romanian R&D sector

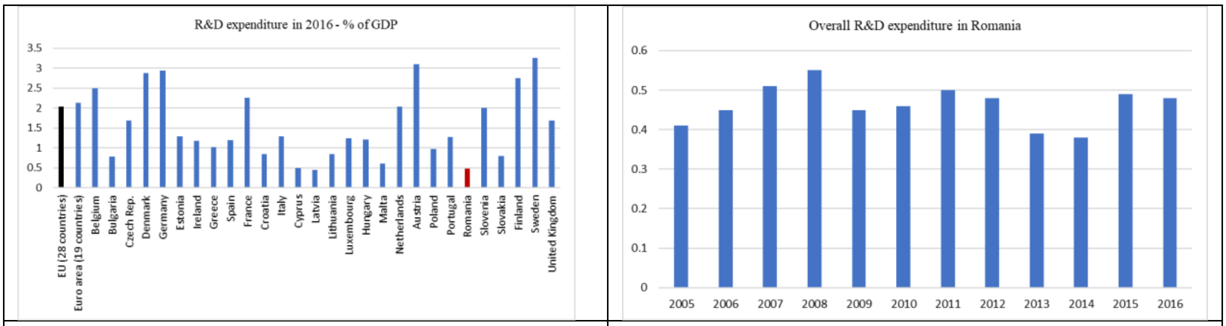
The Romanian R&D sector is largely dominated by the public ownership. The R&D activity is performed by two distinct categories of institutions. On the one hand, the scientific research is conducted by universities and by the research institutes of the Romanian Academy. On the other hand, the applied R&D activity is performed by private firms of public companies which are represented by independent research institutes. Our focus is on the second category of R&D activities and institutions.

The Romanian R&D strategy for the period 2014-2020 shows the necessity to encourage through complex measures the R&D activity, which is underfinanced (the state involvement in the R&D industry is equivalent with 0.31% of GDP in 2011, whereas the target for 2020 is established at 1% from GDP). The priority domains for the public R&D investment, in agreement with the EU strategy, are[2]: (i) bio-economy, (ii) ICT, (iii) energy, environment and climate change; (iv) eco, nanotechnology, and advanced materials (v) health, (vi) patrimony and cultural identity and (vii) new and emerging technologies.

However, neither the state involvement, or the private sector, succeeded to dynamize the R&D expenditure in Romania over the last decade. According to the Eurostat statistics, Romania lies between last EU countries in terms of R&D expenditure in 2016 (Fig. 1a), overpassing only Latvia, and representing less than 25% of the EU average. Furthermore, although the national strategy foreseen a continuous increase of public funds addressing the R&D activities and supporting the private actions in the R&D sector, the overall (public and private) R&D expenditure remains at less than 0.5% of GDP, with a decrease after the recent global crisis (Fig. 1b).

Figure 1. R&D expenditure in Romania

[2] Romanian Government Decision no. 929 from October 21, 2014 regarding the 'National strategy for research, development and innovation 2014-2020'.



(a) (b)

Source: Eurostat database

4. Data and methodology

4.1. Data

Data with an annual frequency are extracted from AMADEUS (Bureau van Dijk – BvB) database and cover the time span 2006 to 2016. Under the NACE code "72 - Scientific research and development", 135 Romanian companies are included in the database. However, we have retained in our sample 116 firms for which we have found satisfactory data.[3] The companies perform R&D activities with application in various economic fields, the most important being the medical industry (over 20%), material science (18%), socio-economic research (16%) and energy industry (12%). Out of 116 companies, 47 represents national research institutes.

To calculate the TFP, we start from the classic Cobb-Douglas production function whose inputs are the capital and labor:

$$Y = AK^{\alpha}L^{\beta}, \qquad (1)$$

where Y is the output (or the added value of the company (AV)), K is the capital (stock) and L represents the labor (number of employees).

The stock of capital (K) for each firm at each period, is calculated using the Perpetual Inventory Method as follows[4]:

$$K = K_t^{BV} - K_{t-1}^{BV} + DEPR^{BV}, \qquad (2)$$

[3] Only those firms with at least six out of eleven years of observations are retained into analysis. None of the companies made default during the analyzed period.

[4] Calculated this way, the stock of capital might record in specific periods negative values, which renders impossible the use of the log form of Cobb-Douglas function. To overcome this issue, we first identify the minimum value of K variable for the entire sample (MIN_K). Second, we obtain a modified stock of capital series $K'_t = K_t + MIN_K$. Another possibility to overcome the issue of negative values for the stock of capital is to take them out from the sample. However, in this case our panel analysis may suffer from the broken panel bias. While we present in this paper the results using the first option for the stock of capital series, we have also performed all the computations renouncing to negative values. There are not important differences in terms of empirical results (these additional findings can be provided upon request) but we prefer to trust the coefficients of the estimations that avoid the broken panel problem.

where K_t^{BV} and represent K_{t-1}^{BV} the current and respectively the lagged book value of tangible fixed assets, while $DEPR^{BV}$ is the depreciation and amortization.

Applying this method to compute the capital stock determines the loss of data for one year. Consequently, the final data sample covers the period 2007 to 2016.

Starting from Eq. (1), the TFP (our dependent variable) is defined as the output unexplained by the inputs (Ilmakunnas and Miyakoshi, 2013):

$$\ln(A) = \ln(Y) - \alpha \ln(K') - \beta \ln(L) \,, \tag{3}$$

where $\ln(A)$ is equivalent with $\ln(TFP)$.

Unfortunately, the AV data are scarce in the AMADEUS database and we are forced to compute the series. Following the Organisation for Economic Co-operation and Development (OECD) recommendations (see Gal, 2013), the internally computed added value becomes:

$$AV = L_{costs} + EBITDA, \tag{4}$$

where L_{costs} are the labor cost with the employees and $EBITDA$ (Earnings Before Interest Taxes Depreciation and Amortization) is a measure of profits, or a part of income going to the capital.

Our purpose is to see which the drivers of TFP are, and what role the corporate governance has in enhancing TFP. To this hand, in line with other work performed in the literature, we assess the role of firm size (represented by the natural log of total assets – $lnta$), of taxation (measured in terms of taxes to operational revenue ratio – tor), of intangible assets (intangible fixed assets to total assets ratio – $ifatr$) and profit margins (pm).

The shareholders' structure and corporate governance are captured through a series of dummy variables. First, we consider the role of independence in taking decisions and we rely on the BvB independence indicators. Several levels of independence indicators can be identified, ranging from A (low independence characterized by dispersed ownership, where each shareholder detains less the 25% from the total capital) to D (high independence level in taking decisions, with a recorded shareholder with a direct ownership of over 50%), while U is attributed to an unknown level of independence. Our dummy variable ($dummy$ 1) taxes value 1 if the level of independence is high (D) and zero otherwise. Second, we want to see to what extent the foreign ownership influences the R&D companies' performances in terms of TFP. In this line we consider the presence of foreign direct investment (FDI) if the ultimate owner is located outside Romania and detains more than 25% from the total capital

($dummy$ 2 takes value 1 if FDI and 0 otherwise)[5]. Third, we construct a dummy variable ($dummy$ 3) which takes value 1 if directors/managers are also a shareholder, and 0 otherwise.[6] We want to see to what extent a direct involvement of shareholders in the firm management influence the overall productivity of the company. Fourth, we have built a gender dummy variable ($dummy$ 4), which takes value 1 if the CEO is a man, and 0 if the CEO is a woman. Women are considered as being more conservative compared to their male counterparts. At the same time, the women's presence in the board of directors underlines the board diversity, which in the corporate governance literature (i.e. Smith et al., 2006) has a positive impact on the company performance. In addition, with women on board, the propensity for risk taking decreases and the decision-making process might be delayed. Finally, we investigate to what extent the private own companies have better productivity performances compared to the state own. Consequently, we have constructed a dummy variable ($dummy$ 5) which takes value 1 if the global ultimate owner is private, and 0 if it is public. Table 1 centralize the explanatory variable and present their expected sign and their use by the previous literature.

Variable	Explanations	Expected sign	Previously employed
lnta	Large companies are financially stable and have more development opportunities. They also realize economies of scales which enhance the productivity level.	+	
tor	A high taxation level negatively affects the output, and therefore the productivity. However, high taxes are equivalent with increased efforts to achieve the operational objectives of firms, which may enhance the productivity level through cost control.	-/+	
ifatr	For industrial firms the high level of intangible assets is a signed of a deeper involvement in R&D activities. Nevertheless, for R&D companies which are supposed to generate innovation, a high book value of intangible assets may show their dependence on other innovation companies, which in turns, may negatively affect the TFP.	+/-	
pm	An increased profit margin is a sign of profitability and performant activity, which increase the productivity level.	+	
dummy1	If the level of independence is very high, the decision process became faster, which may increase the productivity. At the same time, the level of risk may increase given a reduced cooperation in the decision-making process.	+/-	
dummy2	The presence of foreign ownership is expected to bring a plus of productivity given the know-how transfer.	+	
dummy3	If the managers are also shareholders, the level of decisional	+/-	

[5] If we consider, for example, the FDI presence if the ultimate foreign shareholder detains at least 50% of the company capital, dummy 2 variable remains near the same. However, we have retrained the 25% threshold for the FDI presence.

[6] Interesting to note, except for five companies, the managerial team in its totality is, or is not, shareholder. For the five companies were only a part of the managerial team is also a shareholder, we have awarded value 1 for the variable dummy3.

	independence increases, and also the accountability in taking decisions. At the same, time, the lack of expertise and the failure to use a professional managerial team, may lead to a negative effect on the productivity level.	
dummy4	The gender diversity contributes to more equilibrate decisions. However, women on board reduce the propensity for risk taking which may lead to missed investment opportunities.	+/-
dummy5	The private sector is considered more productive compared with the public one, especially in transition economies. At the same time, the state-owned companies have a better access to finance and might benefits from public contracts.	+/-

Note: lnta = total assets (natural log), tor = taxes to operational revenue ratio, iftar = intangible assets to total assets ratio, pm = profit margin, dummy1 = 1 if independence and 0 otherwise, dummy2 = 1 if FDI and 0 otherwise, dummy3 = 1 if manager-shareholder and 0 otherwise, dummy4 = 1 if manager is a man and 0 if women, dummy5 = 1 if private company and 0 if public

4.2. Methodology

4.2.1. TFP calculation

A simple way to estimate the TFP on firm-level data, is to take the residuals from the from OLS regression when estimating the production function (Gal, 2013). The obtained coefficients, may, however, be biased if higher productivity firms hire more workers. That is, a positive correlation may exist between the labor input and the error term (that is, the TFP). The fixed effect OLS model may partially correct this bias as it considers time-invariant firm-specific productivity effects but cannot control for different productivity shocks across firms. Therefore, building upon the semi-parametric approach advanced by Olley and Pakes (1996) who use the investment as a proxy variable for unobserved TFP, Levinsohn and Petrin (2003) employ intermediate inputs (m) as proxies. The TFP is thus estimated in a panel framework using the log-linear specification of the production function:

$$Y_{it} = c + \alpha K_{it} + \beta L_{it} + \varepsilon_{it}, \quad (5)$$

where Y is the internally computed value added, K is the stock of capital, L is the number of employees, i = 1,…,116 firms, t = 2007,…,2016 and ε_{it} is the error term that can be decomposed as follows:

$$\varepsilon_{it} = \omega_{it} + \delta_{it}, \quad (6)$$

with ω_{it} representing the productivity of firm i at time t, and δ_{it} being a stochastic error term that contains unobserved productivity shocks which are not correlated with the inputs (e.g. labor).

Given that the productivity ω_{it} is known to the firm and the firm may decide to increase the inputs in the case of a positive productivity shock, a simultaneity problem may appear, which is treated by Levinsohn and Petrin (2003) by the identification of demand for intermediate goods and by the application of a two-step procedure (for a detailed discussion, see Aiello et al., 2015). The authors include m_{it} in the estimated equation and assume that they depend on K_{it} and ω_{it}, namely $m_{it} = f(\omega_{it} + K_{it})$, a function that is invertible. Therefore, $\omega_{it} = h(m_{it} + K_{it})$, and might be substituted in Eq. (5) as follows:

$$Y_{it} = c + \alpha K_{it} + \beta L_{it} + h(m_{it} + K_{it}) + \delta_{it}, t = 1 \dots T. \quad (7)$$

However, Ackerberg et al. (2006) show that the joint consideration of input variables nonparametric polynomial terms and their structural coefficients in the production function makes the latter potentially unidentified. In addition, the assumptions made by Levinsohn and Petrin (2003) to restrict the dynamics in the productivity process, namely $E(\omega_{it}|\omega_{it-1}, \dots, \omega_{i1} = E(\omega_{it}|\omega_{it-1})$ and $a_{it} = \omega_{it} - E(\omega_{it}|\omega_{it-1})$ which shows that K_{it} is uncorrelated with the innovation a_{it} are not sufficient. Therefore, building upon Levinsohn and Petrin (2003), Wooldridge (2009) proposes a one-step General Method of Moments (GMM) procedure with consistent standard errors. Consequently, different instruments for different equations are specified while $\omega_{it} = f[h(m_{it-1} + K_{it-1})] + a_{it}$. Plugging ω_{it} in Eq. (7) gives:

$$Y_{it} = c + \alpha K_{it} + \beta L_{it} + f[h(m_{it-1} + K_{it-1})] + a_{it} + \delta_{it}. \quad (8)$$

The two equations that identifies α and β are Eq. (7) and:

$$Y_{it} = c + \alpha K_{it} + \beta L_{it} + f[h(m_{it-1} + K_{it-1})] + u_{it}, t = 2 \dots T, \quad (9)$$

where $u_{it} \equiv a_{it} + \delta_{it}$.

Eqs. (7) and (9) shows that in the estimation are used contemporaneous state variables K_{it}, any lagged inputs, and functions of these, as instrumental variables (Wooldridge, 2009).

4.2.2. Bootstrap panel quantiles regression

The general tested equation is:

$$tfp_{it} = \alpha + \beta 1_{it} lnta + \beta 2_{it} tor + \beta 3_{it} iftar + \beta 4_{it} pm + \beta 5_{it} dummy1 + \beta 6_{it} dummy2 + \beta 7_{it} dummy3 + \beta 8_{it} dummy4 + \beta 9_{it} dummy5 + \varepsilon_{it}. \quad (10)$$

where tfp_{it} is the total factor productivity estimated through Wooldridge (2009), Levinsohn and Petrin (2003), OLS residuals and fixed effect model residuals, α is the intercept, β represents the coefficients, ε_{it} is the error term.

However, variables may have different effects at different points in the conditional distribution of the dependent variable, which recommends the use of a quantile regression. The quantile regression linear model advanced by Koenker and Bassett (1978) supposes a set of random variables $Y_1, Y_2, \ldots$ generated by a linear regression (Hahn, 1995):

$$Y_i = \beta_0 + \beta X_i + \varepsilon_i, \quad (11)$$

where X_i are observed variables, β is an unknown coefficient, and ε_i are unobserved errors.

The quantile regression estimator $\hat{\beta}_\tau$ of β_i is defined by:

$$\hat{\beta}_N = \underset{\beta}{\operatorname{argmin}} \sum_{i=1}^{N} q_\tau(Y_i - \beta X_i), \quad (12)$$

where $q_\tau(u) = u(\tau \cdot 1_{|u \geq 0|} - (1-\tau) \cdot 1_{|u<0|})$.

In a panel framework, let $Q_Y(\tau \mid x) := \inf\{q : P(Y \leq q \mid X = x \geq \tau\}$ denote the τ^{th} conditional quantile of Y's response to a vector of covariates $X = x$, so as $0 \leq \tau \leq 1$. In this case, the linear quantile regression model of $Q_{y_{it}}(\tau \mid x_{it})$, at a given τ becomes:

$$Q_{y_{it}}(\tau \mid x_{it}) = \beta_0(\tau) + x'\beta(\tau), \quad (13)$$

where $\beta_0(\tau)$ is a scalar intercept, $\beta(\tau)$ represents a coefficient vector while x' denotes the vector transpose of x.

The choice of τ allows us to focus on the tails of the conditional distribution. However, assessing the accuracy of the τ^{th} quantile parametric regression estimate requires reliable procedures for identifying the asymptotic variance-covariance matrix, particularly for non-iid cases (Galvao and Montes-Rojas, 2015). In this context, the use of bootstrap resampling methods is recommended for the construction of confidence intervals based on quantile regressions.

This is a fully-nonparametric procedure based on the so-called (y_{it}, x_{it})-pairs bootstrap, supposed to be independent. Several possibilities exist for bootstrap resampling, while the cross-sectional and temporal resampling represents the simplest methods (Kapetanios, 2008). In the first case a replacement from the cross-section dimension with probability $1/N$ is performed. For both vectors $Y^* = (y_{i1}, \ldots, y_{is}, \ldots, y_{iN})$ and $X^* = (x_{i1}, \ldots, x_{is}, \ldots, x_{iN})$, each element of the vector of indices $(i_1, \ldots, i_N)$ is obtained by drawing with replacement from $(1, \ldots, N)$, each element $y_{i_s} = (y_{i_s1}, \ldots, y_{i_sT})$ and respectively $x_{i_s} = (x_{i_s1}, \ldots, x_{i_sT})$, for $s \in (i_1, \ldots, i_N)$. In the second case, for both Y and X a replacement is made with the temporal dimension for each individual, with probability $1/T$. The implementation construct in the case of Y^*, for each $i \in (1, \ldots, N)$, is $y_i^* = (y_{i_t1}, \ldots, y_{i_tr}, \ldots, y_{i_tT})$, where each element of $(t_1, \ldots, t_T)$ is obtained by drawing with replacement from $(1, \ldots, T)$. Afterwards Y becomes

$Y^* = (y_1^*, \dots, y_i^*, \dots, y_N^*)$, and the same vector of indices is used for obtaining X^*. A combination scheme between the two methods is used. Therefore, for a given τ-quantile of interest, the bootstrapped panel data estimator is:

$$\hat{\beta}_{NT}^* = \underset{\beta}{\operatorname{argmin}} \sum_{i=1}^{N} \sum_{t=1}^{T} q_\tau (y_{it}^* - \beta x_{it}^{*\prime}), \tag{14}$$

where (y_{it}^*, x_{it}^*) are the pairwise resampled data.

5. Results

The panel quantile regression analysis requires stationary series. Therefore, we start our empirical analysis by applying panel unit root tests. Given the fact that we have an unbalanced panel, we use Fisher-type panel unit root tests, proposed by Maddala and Wu (1999) and Choi (2001), tests that combine the p-values of the individuals' statistics. The results are presented in Table A1 (Appendix) and show that our series are stationary.

We continue the empirical exercise with the bootstrap panel quantiles regression (for 11 quantiles from 0.05 to 0.95). In the main analysis 200 iterations are performed. We obtain four sets of results, corresponding to the four approaches of computing TFP. Table 2 presents the results for the Wooldridge's (2009) TFP approach. For all quantiles (that is, for all levels of productivity), the size of the companies has a positive influence on productivity. The economies of scales and the stability of financing sources recorded by larger companies in the R&D sector, lead, therefore, to an increased in the productivity level. A similar influence is exercised by the profit margin, showing that an increased profitability enhances the TFP. However, no significant influence is recorded in the case of taxation ratio, and in the case of intangible assets to total assets ratio. These results might be explained as follows. On the one hand, Romania has in place over the analyzed period a fiscal system relying on a flat tax rate. Although noteworthy fiscal incertitude is recorded during the last years (generated by multiple annual modifications of the fiscal code), there is a minor effect of this incertitude on the companies' activity, including their performances in terms of productivity. On the other hand, for R&D companies, a higher investment is intangible assets (considered by themselves R&D products), does no lead to an increase in the TFP. In fact, for R&D companies the intangible to total assets ratio is smaller compared to manufacturing firms for example.

Several interesting findings are obtained when we assess the influence of corporate governance on TFP. First, for all quantiles the $dummy1$ variable has a negative impact on TFP. This means that a larger independence in making decisions has a negative impact of

TFP. This result shows that it is recommended to collaborate in making decisions and a dispersed ownership is benefic for the overall productivity of R&D companies in Romania. Second, it is very clear that foreign-owned R&D firms unregister better productivity performances compared with their counterparts held by national investors. Thus, the knowledge transfer and management skills are benefic for improving the economic performances of these companies. Third, if the manager of the company is also a shareholder ($dummy3$), this has a negative impact on the firms 'performances, regardless the level of their productivity. This finding is corroborated with the first one, showing that, if there is no control by the owner of the company, the managers tend to take risky decisions with a negative impact on TFP. $Dummy4$ shows that the absence of women from the companies' board, has a negative impact on TFP. This result confirms the theory showing that board diversity has a positive influence on firms' performances. However, the result is significant for lower quantiles only, that is, for companies with a low level of productivity. For higher productivity level, the women presence in the board does not necessarily lead to an increased productivity, which represents an original result of our study. Finally, the state-owned companies record a higher productivity. This result contrast the one showing the positive role of FDI but might be explained by the fact that the private-owned national companies are young firms in the R&D industry and record smaller level of productivity. At the same time, the 47 national research institutes that are mainly held by the state, benefit from state-contracts and have a larger experience in the field, with a positive impact on the TFP. Furthermore, this result is not surprising given that the argument of more efficient private companies is neither rigorously supported by economic theory, nor by empirical evidence (González-Páramo and Hernández De Cos, 2005). In addition, our findings agree with several previous reported findings. While Dimelis and Papaioannou (2016) do not report a significant impact of public ownership on TFP for southern European economies, Gaitán et al. (2018) show that pubic companies perform better in terms of productivity in Latin America.

Table 2. TFP quantile regression – Wooldridge (2009) (200 bootstraps)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
quantiles	0.05	0.15	0.25	0.35	0.45	0.50	0.55	0.65	0.75	0.85	0.95
lnta	0.055***	0.085***	0.115***	0.133***	0.147***	0.152***	0.156***	0.168***	0.187***	0.198***	0.208***
	(0.012)	(0.011)	(0.011)	(0.010)	(0.010)	(0.115)	(0.012)	(0.015)	(0.014)	(0.015)	(0.017)
tor	-0.022	-0.000	0.003	0.018*	0.009	0.006	0.001	-0.001	-0.010	-0.010	0.010
	(0.014)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.010)	(0.010)	(0.013)	(0.025)
ifatr	-0.000	-0.000	-0.000	-0.000	0.000	0.000	0.000	-0.000	-0.000	-0.001	-0.002*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
pm	0.007***	0.008***	0.008***	0.006***	0.007***	0.007***	0.007***	0.007***	0.008***	0.007***	0.002
	(0.001)	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.003)
dummy1	0.034	-0.066***	-0.110***	-0.130***	-0.120***	-0.122***	-0.114***	-0.108***	-0.161***	-0.162***	-0.093
	(0.040)	(0.023)	(0.017)	(0.021)	(0.022)	(0.021)	(0.021)	(0.024)	(0.035)	(0.042)	(0.077)
dummy2	0.133***	0.184***	0.192***	0.174***	0.160***	0.144***	0.154***	0.197***	0.358***	0.408***	0.650***
	(0.041)	(0.030)	(0.020)	(0.024)	(0.024)	(0.025)	(0.032)	(0.060)	(0.062)	(0.094)	(0.097)
dummy3	-0.121***	-0.053**	-0.063**	-0.098***	-0.105***	-0.123***	-0.123***	-0.111***	-0.132***	-0.182***	-0.122
	(0.038)	(0.024)	(0.018)	(0.022)	(0.023)	(0.022)	(0.021)	(0.030)	(0.039)	(0.003)	(0.076)
dummy4	-0.090***	-0.077***	-0.061***	-0.056***	-0.037**	-0.025	-0.016	0.010	0.031	0.021	-0.006
	(0.028)	(0.020)	(0.019)	(0.020)	(0.018)	(0.018)	(0.018)	(0.027)	(0.028)	(0.038)	(0.048)
dummy5	-0.109***	-0.166***	-0.172***	-0.152***	-0.162***	-0.171***	-0.181***	-0.199***	-0.171***	-0.112	-0.297**
	(0.039)	(0.027)	(0.023)	(0.033)	(0.037)	(0.039)	(0.034)	(0.044)	(0.061)	(0.074)	(0.149)
constant	5.763***	5.705***	5.574***	5.472***	5.425***	5.418***	5.413***	5.402***	5.400***	5.423***	5.704***
	(0.128)	(0.087)	(0.092)	(0.103)	(0.107)	(0.109)	(0.118)	(0.144)	(0.128)	(0.155)	(0.193)

*Notes: (i) Standard errors in parentheses; (ii) *** p<0.01, ** p<0.05, * p<0.1; (iii) lnta = total assets (natural log), tor = taxes to operational revenue ratio, iftar = intangible assets to total assets ratio, pm = profit margin, dummy1 = 1 if independence and 0 otherwise, dummy2 = 1 if FDI and 0 otherwise, dummy3 = 1 if manager-shareholder and 0 otherwise, dummy4 = 1 if manager is a man and 0 if women, dummy5 = 1 if private company and 0 if public; (iv) 1,055 observations and pseudo R^2=0.441.*

The second set of results based on Levinson and Petrin's (2003) approach for the TFP, reveals slightly different results. On the one the positive impact of firms' size on TFP is recorded for upper-quantiles only, while for the lower-quantiles, the impact is negative. On the other hand, while the influence of profitability remains the same for all quantiles, the taxation level seems to have a significant and positive impact on productivity, showing that in front of an increased taxation companies look for strategies allowing them to preserve their profits, and become more productive (and conversely, if the level of taxation decreases, money is spent less caution and the productivity decreases).

However, in terms of shareholders' structure and governance role in enhancing productivity, the results are quite similar with the previous ones. The degree of independence and the implication of shareholders in the firms' management have a negative impact on TFP, while the FDI has a positive influence. In addition, the absence of women in companies' boards and therefore, the lack of board diversity, negatively influence the TFP, although this finding is documented for middle- and upper-quantiles only. Finally, the private ownership negatively influences the R&D firms' productivity.

Table 3. TFP quantile regression – Levinson and Petrin (2003) (200 bootstraps)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
quantiles	0.05	0.15	0.25	0.35	0.45	0.50	0.55	0.65	0.75	0.85	0.95
lnta	-0.062***	-0.042***	-0.028***	-0.013**	0.000	0.004	0.009**	0.017***	0.025***	0.035***	0.042***
	(0.012)	(0.007)	(0.005)	(0.005)	(0.005)	(0.004)	(0.004)	(0.004)	(0.003)	(0.005)	(0.010)
tor	0.001	0.025**	0.023***	0.015**	0.015**	0.019**	0.020**	0.017***	0.019***	0.021***	0.020***
	(0.027)	(0.012)	(0.007)	(0.006)	(0.008)	(0.008)	(0.008)	(0.006)	(0.006)	(0.007)	(0.007)
ifatr	-0.001**	-0.001***	-0.001***	-0.001***	-0.000***	-0.000***	-0.000**	-0.000**	-0.000**	-0.001***	-0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
pm	0.007**	0.005***	0.005***	0.006***	0.005***	0.005***	0.004***	0.004***	0.004***	0.004***	0.003***
	(0.003)	(0.001)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)
dummy1	-0.074	-0.076***	-0.083***	-0.093***	-0.078***	-0.078***	-0.074***	-0.063***	-0.064***	-0.038	-0.051
	(0.049)	(0.025)	(0.014)	(0.015)	(0.013)	(0.012)	(0.013)	(0.012)	(0.016)	(0.024)	(0.031)
dummy2	0.006	0.027	0.067**	0.073**	0.075***	0.091***	0.100***	0.091***	0.092***	0.126***	0.247***
	(0.067)	(0.036)	(0.030)	(0.033)	(0.025)	(0.022)	(0.018)	(0.019)	(0.024)	(0.032)	(0.049)
dummy3	-0.132**	-0.038	-0.042**	-0.070***	-0.072***	-0.064***	-0.059***	-0.059***	-0.082***	-0.059**	-0.011
	(0.055)	(0.026)	(0.020)	(0.025)	(0.020)	(0.018)	(0.017)	(0.015)	(0.016)	(0.024)	(0.032)
dummy4	0.041	0.015	-0.007	-0.027**	-0.020*	-0.032**	-0.038***	-0.043***	-0.060***	-0.063***	-0.076***
	(0.049)	(0.028)	(0.015)	(0.012)	(0.011)	(0.012)	(0.013)	(0.014)	(0.016)	(0.019)	(0.024)
dummy5	-0.088	-0.097***	-0.105***	-0.083***	-0.069***	-0.068***	-0.063***	-0.061***	-0.047**	-0.071***	-0.075
	(0.068)	(0.037)	(0.023)	(0.021)	(0.016)	(0.012)	(0.014)	(0.019)	(0.019)	(0.027)	(0.048)
constant	0.293**	0.293**	0.255***	0.198***	0.091*	0.085**	0.055	0.040	0.029	0.029	0.091
	(0.126)	(0.076)	(0.044)	(0.049)	(0.049)	(0.040)	(0.041)	(0.055)	(0.039)	(0.058)	(0.096)

*Notes: (i) Standard errors in parentheses; (ii) *** p<0.01, ** p<0.05, * p<0.1; (iii) lnta = total assets (natural log), tor = taxes to operational revenue ratio, iftar = intangible assets to total assets ratio, pm = profit margin, dummy1 = 1 if independence and 0 otherwise, dummy2 = 1 if FDI and 0 otherwise, dummy3 = 1 if manager-shareholder and 0 otherwise, dummy4 = 1 if manager is a man and 0 if women, dummy5 = 1 if private company and 0 if public; (iv) 1,055 observations and pseudo R^2=0.220.*

Tables 4 and 5 presents the results of estimation relying on the OLS residuals and FE model residuals, for computing the TFP. Several conclusions can be drawn starting from these findings. First, there is a large correspondence between the results of these two estimations, which confirms the findings reported by Gal (2013). Second, the results reported in Tables 4 and 5 confirms our initial findings relying on Wooldridge (2009), proving thus their robustness (a small exception appears in the case of pm, whose influence on TFP is not significant). More precisely, the firms size matters at all level of productivity. Although marginal, the effect of $ifatr$ becomes positive, opposed to the results reported in Table 3. In addition, the impact of degree of independence in making decisions and the implication of shareholders in the companies' management, negatively impacts the TFP. As in the previous cases, the FDI positively influence the productivity level, while the state-owned companies record better performances. Mixed findings are obtained when we assess the presence of women on board. While the women implication in firms' management has a positive impact on productivity for lower-quantiles, it has a negative impact for high-productivity firms. All in all, the presence of women on board across the four sets of results leads to mixed findings.

Table 4. TFP quantile regression – OLS residuals (200 bootstraps)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
quantiles	0.05	0.15	0.25	0.35	0.45	0.50	0.55	0.65	0.75	0.85	0.95
lnta	0.117***	0.154***	0.182***	0.193***	0.198***	0.190***	0.188***	0.183***	0.196***	0.211***	0.230***
	(0.020)	(0.015)	(0.013)	(0.011)	(0.008)	(0.007)	(0.007)	(0.007)	(0.011)	(0.012)	(0.016)
tor	0.003	0.002	-0.007	-0.002	-0.009	-0.015	-0.019**	-0.016**	-0.006	-0.012	-0.019
	(0.024)	(0.014)	(0.013)	(0.012)	(0.010)	(0.010)	(0.009)	(0.007)	(0.013)	(0.011)	(0.016)
ifatr	-0.000	-0.001**	-0.000	0.000	0.000*	0.000**	0.001***	0.001***	0.001***	0.002***	0.004***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
pm	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)	(0.002)
dummy1	-0.267***	-0.227***	-0.165***	-0.126***	-0.102***	-0.086***	-0.072***	-0.052**	-0.005	0.004	0.132**
	(0.051)	(0.062)	(0.060)	(0.041)	(0.021)	(0.019)	(0.020)	(0.021)	(0.034)	(0.030)	(0.061)
dummy2	0.594***	0.215*	0.143**	0.067	0.094***	0.082***	0.078**	0.096***	0.087**	0.087*	0.013
	(0.094)	(0.117)	(0.062)	(0.048)	(0.035)	(0.030)	(0.032)	(0.029)	(0.038)	(0.050)	(0.066)
dummy3	0.069	-0.060	-0.083	-0.080	-0.060*	-0.061**	-0.062**	-0.084***	-0.034	-0.035	-0.111*
	(0.123)	(0.117)	(0.062)	(0.054)	(0.034)	(0.026)	(0.027)	(0.025)	(0.047)	(0.042)	(0.065)
dummy4	-0.158***	-0.048*	0.016	0.029	0.036	0.036*	0.036*	0.063***	0.083***	0.083***	0.071
	(0.045)	(0.025)	(0.031)	(0.026)	(0.022)	(0.021)	(0.020)	(0.018)	(0.029)	(0.027)	(0.057)
dummy5	-0.731***	-0.318**	-0.228***	-0.210***	-0.218***	-0.245***	-0.263***	-0.271***	-0.288***	-0.285***	-0.314***
	(0.091)	(0.0141)	(0.062)	(0.053)	(0.035)	(0.030)	(0.028)	(0.030)	(0.038)	(0.031)	(0.073)
constant	6.717***	6.476***	6.264***	6.199***	6.185***	6.290***	6.331***	6.386***	6.311***	6.250***	6.149***
	(0.202)	(0.146)	(0.132)	(0.110)	(0.081)	(0.070)	(0.069)	(0.067)	(0.109)	(0.110)	(0.153)

*Notes: (i) Standard errors in parentheses; (ii) *** p<0.01, ** p<0.05, * p<0.1; (iii) lnta = total assets (natural log), tor = taxes to operational revenue ratio, iftar = intangible assets to total assets ratio, pm = profit margin, dummy1 = 1 if independence and 0 otherwise, dummy2 = 1 if FDI and 0 otherwise, dummy3 = 1 if manager-shareholder and 0 otherwise, dummy4 = 1 if manager is a man and 0 if women, dummy5 = 1 if private company and 0 if public; (iv) 1,055 observations and pseudo R^2=0.425.*

Table 5. TFP quantile regression – OLS with FE residuals (200 bootstraps)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
quantiles	0.05	0.15	0.25	0.35	0.45	0.50	0.55	0.65	0.75	0.85	0.95
lnta	0.076***	0.086***	0.103***	0.114***	0.113***	0.110***	0.106***	0.104***	0.102***	0.115***	0.128***
	(0.011)	(0.009)	(0.009)	(0.008)	(0.006)	(0.005)	(0.004)	(0.004)	(0.007)	(0.007)	(0.010)
tor	0.004	0.001	-0.003	-0.005	-0.006	-0.007	-0.007	-0.008	-0.002	-0.003	-0.011
	(0.014)	(0.008)	(0.007)	(0.007)	(0.006)	(0.006)	(0.005)	(0.005)	(0.008)	(0.007)	(0.009)
ifatr	-0.000	-0.000*	-0.000	0.000	0.000**	0.000**	0.000***	0.000***	0.000**	0.001***	0.002***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
pm	-0.000	-0.000	0.000	0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
dummy1	-0.151***	-0.137***	-0.097**	-0.080***	-0.056***	-0.052***	-0.039***	-0.031***	-0.008	-0.005	0.069**
	(0.029)	(0.040)	(0.040)	(0.026)	(0.013)	(0.011)	(0.012)	(0.011)	(0.020)	(0.014)	(0.029)
dummy2	0.322***	0.135**	0.077**	0.043	0.052**	0.043**	0.052**	0.055***	0.065***	0.056**	0.026
	(0.043)	(0.067)	(0.039)	(0.028)	(0.021)	(0.019)	(0.022)	(0.016)	(0.023)	(0.027)	(0.038)
dummy3	0.002	-0.020	-0.049	-0.052	-0.035	-0.037**	-0.041**	-0.050***	-0.034	-0.037*	-0.080**
	(0.072)	(0.073)	(0.039)	(0.033)	(0.022)	(0.018)	(0.016)	(0.014)	(0.026)	(0.022)	(0.034)
dummy4	-0.080***	-0.022	0.007	0.022	0.021	0.021**	0.029**	0.035***	0.041***	0.046***	0.042
	(0.027)	(0.015)	(0.019)	(0.017)	(0.013)	(0.012)	(0.012)	(0.011)	(0.015)	(0.015)	(0.028)
dummy5	-0.418***	-0.195**	-0.127***	-0.114***	-0.124***	-0.129***	-0.143***	-0.156***	-0.177***	-0.155***	-0.172***
	(0.045)	(0.087)	(0.046)	(0.035)	(0.025)	(0.051)	(0.018)	(0.016)	(0.021)	(0.017)	(0.035)
constant	6.995***	6.971***	6.832***	6.756***	6.779***	6.821***	6.865***	6.904***	6.955***	6.857***	6.793**
	(0.118)	(0.096)	(0.095)	(0.073)	(0.056)	(0.051)	(0.045)	(0.045)	(0.065)	(0.071)	(0.088)

*Notes: (i) Standard errors in parentheses; (ii) *** p<0.01, ** p<0.05, * p<0.1; (iii) lnta = total assets (natural log), tor = taxes to operational revenue ratio, iftar = intangible assets to total assets ratio, pm = profit margin, dummy1 = 1 if independence and 0 otherwise, dummy2 = 1 if FDI and 0 otherwise, dummy3 = 1 if manager-shareholder and 0 otherwise,* *dummy4 = 1 if manager is a man and 0 if women, dummy5 = 1 if private company and 0 if public; (iv) 1,055 observations and pseudo R^2=0.401.*

Even if we obtain a good correspondence between the four sets of results, there are mixed findings regarding the role of profit margin, intangible assets and women presence on boar, in enhancing the TFP. The number of iterations used for computing the confidence intervals might influence the results. Therefore, we perform a robustness analysis by increasing the number of iterations.

6. Robustness analysis

For our robustness check we use 500 bootstraps. Table 6 presents the new set of finings for the Wooldridge's (2009) approach of TFP, while Tables A2-A4 (Appendix) presents the results for the remaining methodologies used for TFP calculation. As we can notice, the results presented in Table 6 are very closed to the ones reported in Table 2, confirming thus their robustness. The firm size has an important influence on the productivity level, and this influence increases for upper-quantiles, that is, for high-productivity firms. Productivity correlates thus with firm size (Marques, 2015). The profit margin has a marginal but positive influence on TFP, while for the Wooldridge's (2009) method, the estimations shows no role for taxation and intangible assets. At the same time, the degree of decision independence and the combination owner-manager negatively influence the productivity. While FDI positively impact the TFP at all quantiles, the presence of women on board is important only for small-productivity firms. Finally, the public R&D companies from Romania enregister a higher total productivity.

Table 6. TFP quantile regression – Wooldridge (2009) (500 bootstraps)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
quantiles	0.05	0.15	0.25	0.35	0.45	0.50	0.55	0.65	0.75	0.85	0.95
lnta	0.055***	0.085***	0.115***	0.133***	0.141***	0.152***	0.156***	0.168***	0.187***	0.198***	0.208***
	(0.012)	(0.009)	(0.009)	(0.010)	(0.010)	(0.011)	(0.012)	(0.015)	(0.014)	(0.016)	(0.016)
tor	-0.022	-0.000	0.003	0.018*	0.009	0.006	0.001	-0.001	-0.010	-0.001	0.010
	(0.014)	(0.009)	(0.010)	(0.010)	(0.009)	(0.009)	(0.008)	(0.009)	(0.010)	(0.014)	(0.024)
ifatr	-0.000	-0.000	-0.000	-0.000	0.000	0.000	0.000	-0.000	-0.000	-0.000	-0.000**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
pm	0.007***	0.008***	0.008***	0.006***	0.007***	0.007***	0.007***	0.007***	0.008***	0.007***	0.002
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.003)
dummy1	0.034	-0.066***	-0.110***	-0.130***	-0.120***	-0.122***	-0.114***	-0.108***	-0.161***	-0.162***	-0.093
	(0.037)	(0.023)	(0.018)	(0.021)	(0.023)	(0.023)	(0.022)	(0.027)	(0.038)	(0.045)	(0.071)
dummy2	0.133***	0.184***	0.192***	0.174***	0.160***	0.144***	0.154***	0.197***	0.358***	0.408***	0.650***
	(0.047)	(0.028)	(0.021)	(0.025)	(0.026)	(0.028)	(0.035)	(0.063)	(0.068)	(0.089)	(0.109)
dummy3	-0.121***	-0.053**	-0.063***	-0.098***	-0.105***	-0.123***	-0.123***	-0.111***	-0.132***	-0.182***	-0.122
	(0.039)	(0.026)	(0.020)	(0.022)	(0.024)	(0.023)	(0.022)	(0.029)	(0.041)	(0.059)	(0.075)
dummy4	-0.090***	-0.077***	-0.061***	-0.056***	-0.037**	-0.025	-0.016	0.010	0.031	0.021	-0.006
	(0.027)	(0.018)	(0.017)	(0.019)	(0.018)	(0.018)	(0.019)	(0.024)	(0.029)	(0.037)	(0.049)
dummy5	-0.109**	-0.166***	-0.172***	-0.152***	-0.162***	-0.171***	-0.181***	-0.199***	-0.171***	-0.112	-0.297**
	(0.044)	(0.029)	(0.022)	(0.033)	(0.037)	(0.038)	(0.037)	(0.044)	(0.061)	(0.071)	(0.134)
constant	5.763***	5.705***	5.574***	5.472***	5.425***	5.418***	5.413***	5.402***	5.400***	5.423***	5.704***
	(0.123)	(0.077)	(0.081)	(0.100)	(0.104)	(0.108)	(0.115)	(0.141)	(0.136)	(0.164)	(0.184)

*Notes: (i) Standard errors in parentheses; (ii) *** $p<0.01$, ** $p<0.05$, * $p<0.1$; (iii) lnta = total assets (natural log), tor = taxe to operational revenue ratio, iftar = intangible assets to total assets ratio, pm = profit margin, dummy1 = 1 if independenc and 0 otherwise, dummy2 = 1 if FDI and 0 otherwise, dummy3 = 1 if manager-shareholder and 0 otherwise, dummy4 = 1 manager is a man and 0 if women, dummy5 = 1 if private company and 0 if public; (iv) 1,055 observations and pseud R^2=0.441.*

7. Conclusions

This paper computes the TFP and investigates its drivers, with a focus on the R&D from Romania. Using firm-level data for the period 2007 to 2016 and different approaches for the TFP calculation, we rely on two main categories of productivity determinants, namely firms' financial performances and innovation capacity, and corporate governance elements.

Our bootstrap panel quantiles regressions show that firms' size and their profitability margins are important drivers of TFP for R&D companies, while the effect of taxation is not significant. At the same time, the role of intangible assets for the companies acting in the R&D sector is rather not significant.

The corporate governance drivers show that the presence of women on board is important, but only for low-productivity firms. In addition, the independence of the decision-making process and the CEO duality negatively impact TFP for all categories of firms, regardless their level of productivity. This result is consistent with the agency cost theory. Further, as expected, the foreign ownership has a positive and significant influence on the productivity level, but curiously, state-owned applied research institutes perform better. These opposite findings may be explained by the fact that the FDI is important for private firms, and private foreign-owned firms performs better compared with the private domestic-owned companies. However, the public institute may record better performances given the lack of financial constraints and their access to public contracts.

Our results are robust to different TFP specification and to a different number of iterations used for computing the confidence intervals. At the same time, the results have policy implications for the Romanian authorities, which shall encourage the FDI in the private R&D sector on the one hand and consolidate the performant public research institutes on the other hand. Regardless the ownership structure and origin, the board diversity (i.e. presence of women on board) is important in enhancing the TFP level for low-productivity firms. Finally, a separation between firms' management and ownership is necessary to increase the productivity.

For the private investors, our results indicate a positive role of firms' financial performances and firms' size in augmenting the level of overall productivity. Foreign firms should look for niche R&D activities to obtain better productivity performances. Apparently, a direct competition with state-owned institutes is not benefic, given the higher TFP performances recorded by the second category of firms.

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Appendix

Table A1. Panel unit root tests (Fisher-type tests)

Tests \ Variables	tfp1	tfp2	tfp3	tfp4	lnta	tor	iftar	pm
Inverse chi-squared (P)	743.4***	738.5***	899.5***	832.6***	525.2***	957.8***	635.4***	789.3***
Inverse normal (Z)	-8.946***	-10.32***	-7.754***	-5.498***	-3.665***	-14.77***	-5.696***	-11.70***
Inverse logit t (L*)	-14.53***	-15.22***	-16.34***	-14.24***	-7.639***	-22.41***	-11.03***	-17.21***
Modified inverse chi-squared (Pm)	24.13***	23.90***	31.44***	28.31***	13.92***	34.17***	19.07***	26.28***

*Notes: (i) H0 = all panels contains unit roots; (ii) *** p<0.01, ** p<0.05, * p<0.1; (iii) tfp1 = Wooldridge(2009) measure of TFP, tfp2 = Levinsohn and Petrin (2003) measure of TFP, tfp3 = OLS based measure of TFP, tfp4 = OLS with fixed effects measure of TFP, lnta = total assets (natural log), tor = taxes to operational revenue ratio, iftar = intangible assets to total assets ratio, pm = profit margin.*

Table A2. TFP quantile regression – Levinson and Petrin (2003) (500 bootstraps)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
quantiles	0.05	0.15	0.25	0.35	0.45	0.50	0.55	0.65	0.75	0.85	0.95
lnta	-0.062***	-0.042***	-0.028***	-0.013***	0.000	0.004	0.009**	0.017***	0.025***	0.035***	0.042***
	(0.011)	(0.007)	(0.004)	(0.004)	(0.004)	(0.003)	(0.004)	(0.004)	(0.003)	(0.004)	(0.009)
tor	0.001	0.025**	0.023***	0.015**	0.015**	0.019**	0.020**	0.017**	0.019***	0.021***	0.020**
	(0.027)	(0.012)	(0.007)	(0.007)	(0.007)	(0.008)	(0.008)	(0.006)	(0.006)	(0.007)	(0.007)
ifatr	-0.001**	-0.001***	-0.001***	-0.001***	-0.000***	-0.000***	-0.000***	-0.001**	-0.000**	-0.001***	-0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
pm	0.007**	0.005***	0.005***	0.006***	0.005***	0.005***	0.004***	0.004***	0.004***	0.004***	0.003***
	(0.003)	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)	(0.001)
dummy1	-0.074	-0.076***	-0.084***	-0.093***	-0.078***	-0.078***	-0.074***	-0.063***	-0.064***	-0.038	-0.051
	(0.052)	(0.028)	(0.014)	(0.016)	(0.012)	(0.013)	(0.013)	(0.014)	(0.016)	(0.023)	(0.031)
dummy2	0.006	0.027	0.067**	0.073**	0.075***	0.091***	0.100***	0.091***	0.092***	0.126***	0.247***
	(0.061)	(0.034)	(0.030)	(0.035)	(0.025)	(0.021)	(0.017)	(0.018)	(0.023)	(0.033)	(0.047)
dummy3	-0.132**	-0.038	-0.042**	-0.070***	-0.072***	-0.064	-0.059***	-0.059***	-0.082***	-0.059**	-0.011
	(0.058)	(0.030)	(0.021)	(0.025)	(0.020)	(0.018)	(0.017)	(0.016)	(0.161)	(0.023)	(0.032)
dummy4	0.041	0.015	-0.007	-0.027**	-0.020*	-0.032**	-0.038***	-0.043***	-0.060***	-0.063***	-0.076***
	(0.047)	(0.027)	(0.016)	(0.013)	(0.012)	(0.012)	(0.012)	(0.014)	(0.016)	(0.018)	(0.023)
dummy5	-0.088	-0.097**	-0.105***	-0.083***	-0.069***	-0.068***	-0.063***	-0.061***	-0.047**	-0.071***	-0.075
	(0.071)	(0.039)	(0.024)	(0.022)	(0.016)	(0.014)	(0.015)	(0.020)	(0.019)	(0.026)	(0.047)
constant	0.293**	0.293**	0.255***	0.198***	0.091**	0.085**	0.055	0.040	0.029	0.029	0.091
	(0.120)	(0.072)	(0.041)	(0.045)	(0.044)	(0.035)	(0.037)	(0.048)	(0.037)	(0.050)	(0.093)

*Notes: (i) Standard errors in parentheses; (ii) *** p<0.01, ** p<0.05, * p<0.1; (iii) lnta = total assets (natural log), tor = taxes to operational revenue ratio, iftar = intangible assets to total assets ratio, pm = profit margin, dummy1 = 1 if independence and 0 otherwise, dummy2 = 1 if FDI and 0 otherwise, dummy3 = 1 if manager-shareholder and 0 otherwise, dummy4 = 1 if manager is a man and 0 if women, dummy5 = 1 if private company and 0 if public; (iv) 1,055 observations and pseudo R^2=0.220.*

Table A3. TFP quantile regression – OLS residuals (500 bootstraps)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
quantiles	0.05	0.15	0.25	0.35	0.45	0.50	0.55	0.65	0.75	0.85	0.95
lnta	0.117***	0.154***	0.182***	0.193***	0.198***	0.190***	0.188***	0.183***	0.196***	0.211***	0.230***
	(0.021)	(0.017)	(0.014)	(0.013)	(0.010)	(0.008)	(0.008)	(0.007)	(0.011)	(0.012)	(0.016)
tor	0.003	0.002	-0.007	-0.002	-0.009	-0.015	-0.019**	-0.016*	-0.006	-0.012	-0.019
	(0.024)	(0.014)	(0.012)	(0.012)	(0.010)	(0.009)	(0.009)	(0.008)	(0.014)	(0.010)	(0.014)
ifatr	-0.000	-0.001**	-0.000	0.000	0.000*	0.000**	0.001***	0.001***	0.001***	0.002***	0.004***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
pm	-0.000	-0.000	0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)
dummy1	-0.265***	-0.227***	-0.165**	-0.126***	-0.102***	-0.086***	-0.072***	-0.052**	-0.005	0.004	0.132**
	(0.050)	(0.067)	(0.066)	(0.042)	(0.024)	(0.021)	(0.021)	(0.021)	(0.032)	(0.026)	(0.053)
dummy2	0.594***	0.215*	0.143**	0.067	0.094***	0.082***	0.078**	0.096***	0.087**	0.087*	0.013
	(0.095)	(0.116)	(0.062)	(0.049)	(0.036)	(0.031)	(0.033)	(0.029)	(0.041)	(0.046)	(0.067)
dummy3	0.069	-0.060	-0.083	-0.080	-0.060	-0.061**	-0.062**	-0.084***	-0.034	-0.035	-0.111*
	(0.122)	(0.120)	(0.064)	(0.056)	(0.038)	(0.027)	(0.026)	(0.024)	(0.045)	(0.040)	(0.062)
dummy4	-0.158***	-0.048*	0.016	0.029	0.036	0.036	0.036*	0.063***	0.083***	0.083***	0.071
	(0.047)	(0.028)	(0.033)	(0.027)	(0.024)	(0.022)	(0.022)	(0.017)	(0.028)	(0.027)	(0.050)
dummy5	-0.731***	-0.318**	-0.228***	-0.210***	-0.218***	-0.245***	-0.263***	-0.271***	-0.288***	-0.283***	-0.314***
	(0.082)	(0.142)	(0.069)	(0.054)	(0.035)	(0.030)	(0.028)	(0.029)	(0.037)	(0.031)	(0.071)
constant	6.717***	6.476***	6.264***	6.199***	6.185***	6.290***	6.331***	6.386***	6.311***	6.250***	6.149***
	(0.208)	(0.162)	(0.143)	(0.127)	(0.100)	(0.081)	(0.079)	(0.072)	(0.107)	(0.111)	(0.150)

*Notes: (i) Standard errors in parentheses; (ii) *** p<0.01, ** p<0.05, * p<0.1; (iii) lnta = total assets (natural log), tor = taxes to operational revenue ratio, iftar = intangible assets to total assets ratio, pm = profit margin, dummy1 = 1 if independence and 0 otherwise, dummy2 = 1 if FDI and 0 otherwise, dummy3 = 1 if manager-shareholder and 0 otherwise, dummy4 = 1 if manager is a man and 0 if women, dummy5 = 1 if private company and 0 if public; (iv) 1,055 observations and pseudo R^2=0.425.*

Table A4. TFP quantile regression – OLS with FE residuals (500 bootstraps)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
quantiles	0.05	0.15	0.25	0.35	0.45	0.50	0.55	0.65	0.75	0.85	0.95
lnta	0.076***	0.086***	0.103***	0.114***	0.113***	0.110***	0.106***	0.104***	0.102***	0.115***	0.128***
	(0.011)	(0.009)	(0.008)	(0.007)	(0.005)	(0.004)	(0.004)	(0.004)	(0.006)	(0.007)	(0.010)
tor	0.004	0.001	-0.003	-0.005	-0.006	-0.007	-0.007	-0.008*	-0.002	-0.003	-0.011
	(0.015)	(0.008)	(0.007)	(0.007)	(0.006)	(0.006)	(0.005)	(0.005)	(0.008)	(0.006)	(0.008)
ifatr	-0.000	-0.000**	-0.000	0.000	0.000**	0.000***	0.000***	0.000***	0.000***	0.001***	0.002***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
pm	-0.000	-0.000	0.000	0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
dummy1	-0.151***	-0.137***	-0.097**	-0.080***	-0.056***	-0.052***	-0.039***	-0.031***	-0.008	-0.005	0.069**
	(0.031)	(0.041)	(0.038)	(0.025)	(0.013)	(0.012)	(0.011)	(0.011)	(0.020)	(0.016)	(0.030)
dummy2	0.322***	0.135**	0.077*	0.043	0.052**	0.043**	0.052***	0.055***	0.065***	0.056**	0.026
	(0.049)	(0.068)	(0.041)	(0.031)	(0.022)	(0.019)	(0.019)	(0.016)	(0.022)	(0.025)	(0.035)
dummy3	0.002	-0.020	-0.049	-0.052*	-0.035*	-0.037**	-0.041***	-0.050***	-0.034	-0.037*	-0.080**
	(0.071)	(0.070)	(0.038)	(0.031)	(0.208)	(0.017)	(0.015)	(0.011)	(0.024)	(0.021)	(0.034)
dummy4	-0.080***	-0.022	0.007	0.022	0.021	0.021*	0.029**	0.035***	0.041***	0.046***	0.042
	(0.027)	(0.015)	(0.018)	(0.016)	(0.013)	(0.012)	(0.012)	(0.011)	(0.015)	(0.015)	(0.031)
dummy5	-0.418***	-0.195**	-0.127***	-0.114***	-0.124***	-0.129***	-0.143***	-0.156***	-0.177***	-0.155***	-0.172***
	(0.047)	(0.080)	(0.040)	(0.033)	(0.021)	(0.019)	(0.016)	(0.016)	(0.022)	(0.016)	(0.037)
constant	6.995***	6.971***	6.832***	6.756***	6.779***	6.821***	6.864***	6.904***	6.955***	6.857***	6.793***
	(0.119)	(0.088)	(0.086)	(0.067)	(0.050)	(0.045)	(0.040)	(0.039)	(0.062)	(0.064)	(0.088)

*Notes: (i) Standard errors in parentheses; (ii) *** p<0.01, ** p<0.05, * p<0.1; (iii) lnta = total assets (natural log), tor = taxes to operational revenue ratio, iftar = intangible assets to total assets ratio, pm = profit margin, dummy1 = 1 if independence and 0 otherwise, dummy2 = 1 if FDI and 0 otherwise, dummy3 = 1 if manager-shareholder and 0 otherwise, dummy4 = 1 if manager is a man and 0 if women, dummy5 = 1 if private company and 0 if public; (iv) 1,055 observations and pseudo R^2=0.401.*