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Research article

Intellectual capital and high-tech firms' financing choices in the European context: a panel data analysis

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Abstract: This paper seeks to analyse the relationships between listed high-tech firms' financing choices and intellectual capital (IC). It also analyses the impact of ownership concentration on IC investments in high-tech firms. The data set was gathered from the Datastream database for a sample of listed high-tech firms in 14 Western European countries for the period between 2004 and 2015. The data set has an unbalanced panel structure, with the number of years of observations on each firm varying between 3 and 12. We use dynamic panel data models, the GMM system (1998) estimator. Results suggest that internal finance and equity issues are positively while debt is negatively related to IC in high-tech firms. High-tech firms seem to rely on equity issues and internal finance, avoiding debt to fund IC assets. Ownership concentration is negatively related to IC investments in high-tech firms. To the authors' knowledge, this is the first study exploring the relationships between financing choices and IC in high-tech firms. The findings also contribute to the literature by analysing the impact of ownership concentration on IC investments of high-tech firms.

Keywords: dynamic panel data; financing choices; high-tech firms; intellectual capital

JEL Codes: G32

1. Introduction

In a knowledge-based economy, intellectual capital (IC) is considered an important resource for firms' value creation, growth and innovative capacity (Chen et al., 2005; Dzenopoljac et al., 2017; Lev, 2004; Lev and Sougiannis, 1996; Liu and Wong, 2011; Xu and Wang, 2018, 2019). The financial crisis, beginning at the end of 2007, accentuated the scarcity of financial resources as well as the difficulty in accessing funds for investment in intangible assets, namely IC investments (Cincera et al., 2015; Hall et al., 2016). IC investments, without physical or financial form and often referred to as intangible assets, generate future benefits (Lev, 2004) and contribute greatly to value creation through employee knowledge, organizational processes, and innovation (Serenko and Bontis, 2004; Wang et al., 2014). Moreover, IC investments represent an investment in intangible assets and are, often, complementary to tangible investments. However, firms face obstacles in accessing external sources of financing to fund intangible asset investments (Liu and Wong, 2011; Ferrando and Preuss, 2018; Lim et al., 2020).

IC is composed of several components and depending on their nature, namely, when they are not identifiable, they cannot serve as collateral in accessing credit, conversely, tangible assets can serve as collateral, and, therefore, firms with a high level of IC investments faced more obstacles in obtaining finance with favourable terms (Liu and Wong, 2011). Aboody and Lev (2000) argue that information asymmetry between firm insiders and outsiders is more pronounced in firms with a high level of IC investment. IC assets present lower liquidation value due to their inherent liquidity risk. The specificity of IC assets may create adverse selection, moral hazard and opportunistic behaviour in managers (Aboody and Lev, 2000; Brown et al., 2009). These problems may influence intangible-intensive firms' financing decisions (Lev, 2005; Liu and Wong, 2011; Ferrando and Preuss, 2018). In fact, the information opacity associated with intangible assets generates problems of information asymmetry, which is pointed out as one of the reasons why firms with high levels of intangible assets tend to rely on internal funds to fund innovative projects (Carpenter and Petersen, 2002; Hall and Lerner, 2010; Magri, 2014).

In accordance with Myers (1984) and Myers and Majluf (1984), the problems of asymmetric information are greater for firms with a high level of intangible assets due to the specificity of this type of assets, which increases the costs of debt and equity issues. Gatchev et al. (2009) and Hogan and Hutson (2005) conclude that high-tech firms, characterized by high levels of intangible investments, prefer to rely more on equity issues than on debt. These findings reverse the predictions of Pecking Order Theory (POT, henceforth) regarding firms' financing choices.

According to Carpenter and Petersen (2002), the returns of high technology investments are biased, subject to high uncertainty and have a high probability of failure. These factors imply that high-tech firms are strongly affected by capital market imperfections. High-tech firms invest heavily in R&D, which has little collateral value, and so capital market imperfections may impact more strongly on high-tech firms than on firms in other industries (Carpenter and Petersen, 2002). In this way, capital market imperfections may imply debt costs above those of equity issues, given that this last finance source does not require collateral and does not increase the financial risk. Furthermore, when high-tech firms provide detailed, useful information to investors about the sources of firm value creation, information asymmetry diminishes, and thus the cost of equity issues is reduced, and investors' decision-making process is improved (Cronje and Moolman, 2013; Dumay, 2016; Lal Bhasin, 2012; Osinski et al., 2017).

Firms in which R&D and technological innovation assume a prominent role, i.e. high-tech firms, should place greater emphasis on nurturing their intellectual capital. Considering, firstly, that high-tech firms have a fundamental role in providing knowledge for economic growth, and secondly, that these firms seem to face the consequences of capital market imperfections due to the high level of investment in intangible assets, namely IC investment, the current paper seeks to analyse the relationships between IC investment and high-tech firms' financing choices. Moreover, various empirical studies (Saleh et al., 2009; Bohdanovich and Urbanek, 2013; Bohdanovich, 2014) investigated the possible relationship between ownership structure and IC efficiency, providing evidence of a negative effect of insider ownership on IC. Therefore, this paper also analyses the relationship between the IC investment of high-tech firms and ownership concentration.

We consider internal finance, debt and equity issues as potential finance sources used by high-tech firms to fund IC investments. The research sample is composed of non-financial listed high-tech firms in 14 Western European countries for the period between 2004 and 2015. Like Moncada-Paternò-Castello (2016), who followed the European Commission (2006–2014) and OECD (1997) approach, we consider a sample of high-tech firms, in an attempt to capture the relationships between IC and financing sources in this type of firm.

The results suggest that internal finance and equity issues are positively, but debt is negatively related to IC assets in high-tech firms. The findings also suggest that in high-tech firms, ownership concentration impacts negatively on IC investment, suggesting that greater ownership concentration allows more efficient management of financial resources to match the needs for funding investments, namely IC investment. Concerning the impact of the financial crisis of 2008–2009, the results show a negative effect on IC investment.

Our study makes several contributions to the literature. To our knowledge, this is the first study exploring the relationships between finance sources and investment in IC in high-tech firms. In order to obtain a wide perspective of firms' financing choices, we use internal finance, debt and equity issues as financing sources, allowing us to analyse if these firms reverse the predictions of POT in their financing choices. Finally, our findings also contribute to the literature by analysing the impact of ownership concentration on IC investments.

The current paper is structured as follows. In Section 2, we present the theoretical framework and hypothesis formulation; Section 3 presents the methodology; in Section 4, we present the results; the results are discussed in Section 5; and finally, we conclude in Section 6.

2. Intellectual capital and high-techs firms' financing choices

In this study, we consider IC as the knowledge-based activities and processes that contribute to firms' innovation, value creation, competitive advantages and future benefits by adding value for stakeholders (Sardo and Serrasqueiro, 2018). IC assets, without physical or financial form, and often referred to as intangible assets, generate future benefits (Lev, 2004) and greatly contribute to value creation through employee knowledge, organizational processes, and innovation (Serenko and Bontis, 2004; Wang et al., 2014). IC can be decomposed in three components which are widely accepted among researchers (Edvinsson and Malone, 1997; Sydler et al., 2014; Sardo and Serrasqueiro, 2017; Sardo and Serrasqueiro, 2018), i.e., human capital (HC), structural (or organizational) capital (SC), and relational (or customer) capital (RC). Therefore, IC comprises employee knowledge, organizational processes, innovation capabilities, research and development projects, brand and relationships (Serenko and Bontis, 2004; Wang et al., 2014).

The strong embodiment of intangibles increases the sunk costs generated by firms' IC investments (Lev and Zambon, 2003). Firms with high levels of IC may face higher human costs due to the cost of salaries paid to highly trained human resources, such as scientists and engineers (Berk et al., 2010; Porter and Ketels, 2003). Potential earnings will be lost if trained human resources are dismissed or leave the firm.

In accordance with the predictions of pecking order theory (POT, hereafter) (Myers, 1984; Myers and Majluf, 1984), firms prefer internal finance, because it prevents exposure to an information asymmetry problem and is the cheapest source of capital to fund firm activities (Magri, 2014). When internal finance is exhausted, firms rely on external debt, and as a last option, they issue equity. This hierarchical order in the choice of finance sources is explained by the existence of asymmetric information, which may lead to adverse selection problems (Stiglitz and Weiss, 1981), increasing the costs of issuing equity. Some studies conclude that firms with greater asymmetric problems face greater adverse selection problems, and hence, worse conditions when obtaining credit. This adversity in obtaining credit can be diminished if firms possess tangible assets as collateral. Therefore, since firms obtain credit with lower costs than the costs of issuing equity, after internal finance is exhausted, they rely on debt, and issue equity as a last option.

Campello and Giambona (2013) and Qiu and La (2010) find that the redeployability of tangible assets increases borrowing capacity because it allows lenders to recover the credit in the case of borrower bankruptcy. When a firm has assets with lower liquidation values, creditors will establish a high premium risk, which increases the cost of debt. Consequently, firms with activities based on specific assets, such as IC assets, will face difficulties in accessing to credit, therefore they issue equity (Bah and Dumontier, 2001; Hall and Lerner, 2009; Wang and Tornhill, 2010).

Various authors (Carpenter and Petersen, 2002; Hall and Lerner, 2010; Magri, 2014; Myers, 1984; Myers and Majluf, 1984) conclude that high-tech firms prefer internal finance to fund their innovative activities due to the risk associated with such activities. For high-tech firms, several studies show a reverted POT, given that when internal finance is exhausted, these firms prefer to rely on external equity. Intangible assets, such as IC assets, are specific and non-redeployable, and have a low liquidation value, which increases bankruptcy costs and implies a low credit capacity for firms with activities based on such assets (Williamson, 1988). The firms with higher levels of intangible assets should fund their investment in intangible assets, firstly, through internal finance, which allows reduced transaction costs and avoids opportunistic behaviour by managers (Williamson, 1988; Močnik, 2001; Vilasuso and Minkler, 2001).

Prior empirical evidence (Hovakimian et al., 2001; MacKie-Mason, 1990; Titman and Wessels, 1988) showed a negative relationship between firms' intangible assets and leverage. Moreover, studies such as Gatchev et al. (2009), Hogan and Hutson (2005), Magri (2014), Blass and Yosha (2003) and Brown and Petersen (2009) found that high-tech firms prefer external equity to debt. In fact, Carpenter and Petersen (2002) argue that the uncertainty about the returns associated with high-tech investments prevents a high level of debt to avoid negative expectations from investors. Additionally, the problems of adverse selection in credit markets seem to be more acute for high-tech firms, and so lenders can use credit rationing instead of increasing interest rates (Carpenter and Petersen, 2002). Marginal bankruptcy costs may increase quickly for higher levels of debt in high-tech firms, whose activities are based on intangible assets that generate valuable growth opportunities but lose value when firms find themselves in financial distress (Carpenter and Petersen, 2002). In addition, innovative firms face problems of asymmetric information, and therefore, when internal finance is exhausted, this type of firm may choose to fund their activities by issuing equity rather than debt (Gatchev et al., 2009; Hogan and Hutson, 2005; Magri, 2014).

High-tech firms are intensive innovative firms with high level of intangible assets that may influence financing choices. In accordance with Aghion et al. (2004) there are three approaches of the capital structure theory that can explain the financing choices of innovative firms. In accordance with those authors, the approach based on bankruptcy costs argues that costs of bankruptcy are higher for innovative firms with a higher level of intangible assets. According to these authors, for a given level of debt, innovative firms face higher risk of bankruptcy. Consequently, this type of firms should present low level of debt to minimize the bankruptcy costs. Capital structure theory presents another approach based on agency costs and informational asymmetries between firm insiders and outsiders. For this approach, the innovative firms face asymmetric information; thus, equity issues may be a particularly expensive source of finance for these firms. (Aghion et al. 2004). According to Myers and Majluf (1984) firms with activities based on intangible assets are likely to prefer debt instead of equity issues to avoid dilution costs that actual shareholder face would face when firms issue external equity. The last approach of capital structure theory is an alternative to the pecking order theory that suggests that innovative firms may favour new equity rather than debt among these external sources. This is explained by innovative firms facing a lack of tangible assets that can be pledged as collateral, which constrains the access to credit in favourable terms. Therefore, innovative firms choose new equity finance instead of debt for funding their investment in intangible assets.

Various empirical papers (Saleh et al., 2009; Bohdanovich and Urbanek, 2013; Bohdanovich, 2014) investigated a supposed association of ownership structure with IC efficiency, providing evidence of a negative effect of insider ownership on IC measured by the VAIC index (Pulic, 2000). Saleh et al. (2009) studied 264 listed companies in Malaysia during the period 2005–2007 to determine whether there is a relationship between the VAIC, the different forms of ownership structures and profitability. Those authors found a negative and almost always statistically significant relationship between the VAIC, its components and family ownership. They concluded that the negative relationship would increase the likelihood of the opportunistic behavior of family members to the detriment of minority shareholders. Bohdanowicz and Urbanek (2013) investigated a sample of 354 Polish companies listed during the period 2006–2011 for a total of 1505 firm-year observations. The results show a negative and significant relationship between the VAIC and manager ownership Celenza and Rossi (2013) identify a relationship between VAIC and OC that is positive but almost not statistically significant.

Considering the previous arguments, in the current study, we argue that high tech firms which activities are based on intangible assets prefer internal finance and equity issue, avoiding debt for funding IC assets. Additionally, we argue that ownership concentration has a negative relationship with high-tech firms IC.

3. Data, variables and method

3.1. Database

Based on 14 Western European countries (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, Spain, Sweden and the United Kingdom (UK)) for the period between 2004 and 2015, our data were obtained for 821 non-financial, listed, high-tech firms.

A firm is defined as "High-Tech" if its main activity is one of the following: Chemicals, Machinery, Computers, Electrical Machinery, TV-Radio, Medical Equipment, Means of Transport. The data set was gathered from the DataStream database by Thomson Reuters. Therefore, it has an unbalanced panel structure, where the number of years a firm is present in the research sample varies between 3 and 12.

In order to mitigate potential survival bias, Guariglia (2008), Bond et al. (2003) and Cummins et al. (2006) in their studies allow firms' entry and exit is allowed, and using an unbalanced panel partially mitigates potential selection and survivor bias. Following those authors, in the current study firms' entry and exit from the research sample and using an unbalanced panel data allow to control the problem of selection and survival bias. The data was trimmed at one percent tails in order to control for the potential effects of outliers, which may derive from particular events, such as large mergers, errors in coding or firms' extraordinary shocks (Guariglia, 2008).

3.2. Estimation method and variable measurement

This study analyses the relationship between IC and financing choices in high-tech firms resorting to a static panel data model, i.e., pooled OLS, random effects and fixed effects, and a dynamic panel data model, i.e., GMM system (1998).

3.2.1. Static panel data model

This study uses a pooled OLS to estimate the following model:

$$VAIC_{i,t} = \propto_0 + \beta_1 CF_{i,t-1} + \beta_2 TDEBT_{i,t-1} + \beta_3 EqIssue_{i,t-1} + \beta_4 OWNCONC_{i,t-1} + \beta_5 AGE_{i,t-1} + \beta_6 SIZE_{i,t-1} + \beta_7 Dcrisis_{08;09} + e_{i,t} \quad (1)$$

The definition and measurement of the variables of in the Equation (1) are presented in Table 1.

Table 1. Variables and measurement.

Variables	Measurement
Dependent variables	
Intellectual Capital investment ($VAIC_{i,t}$)	$VAIC_{i,t}$ is the value added intellectual coefficient in the current period (VAIC^{TM}) corresponding to the sum of HCE plus SCE plus CEE, where: HCE is human capital efficiency (HCE) = value added (VA)/human capital (HC); SCE structural capital efficiency (SCE) = structural capital (SC)/value added (VA); and CEE is capital employed efficiency = value added (VA)/capital employed (CE), where VA is given by sales—operational expenses except employee costs.
Intangible Assets investment ($InvIntangible_{i,t}$)	Ratio between Intangible Assets in the current period and Total Assets in the current period.
Independent variables	
$Cash\ Flow(\ CF_{i,t})$	Ratio of income plus depreciations and amortization to total assets in the current period.
Total Debt ($TDEBT_{i,t}$)	Ratio of total debt in the current period to total assets in the current period.
Equity issue ($EqIssue_{i,t}$)	Ratio of net equity issues in the current period to total assets in the current period.
Ownership concentration ($OWNCONC_{i,t}$)	Variable NOSHEM (source: Datastream database) that aggregates the percentage of holdings of 5% or more by employees or family members.
Control variables	
Size ($SIZE_{i,t}$)	Natural logarithm of total assets in the current period.
Age ($AGE_{i,t}$)	Natural logarithm of the number of years of the firm's existence in the current period.
Financial Crisis ($Dcrisis_{08;09}$)	Dummy variable representing the financial crisis for the years 2008 and 2009.

The dependent variable used is $VAIC_{i,t}$ as a proxy for IC. The independent variables: $CF_{i,t-1}$ is cash flow in the previous period, $TDEBT_{i,t-1}$ is total debt in the previous period; $EqIssue_{i,t-1}$ is net equity issues in the previous period; $OWNCONC_{i,t-1}$ is ownership concentration in the previous period. The control variables are: $SIZE_{i,t-1}$ is size in the previous period; $AGE_{i,t-1}$ is firm age in the previous period; and $Dcrisis_{08;09}$ is a dummy representing the financial crisis for the years 2008 and 2009.

The pooled OLS does not allow control of firms' individual unobserved effects and therefore Bevan and Danbolt (2004) conclude on the existence of heterogeneity due to not taking into consideration the influence of these effects on the estimated parameters.

The use of fixed effects or random effects panel data allows control of the influence of firms' individual unobserved effects on the estimated parameters. Therefore, considering the unobserved individual effects, the following fixed effects and random effects panel data model is estimated:

$$VAIC_{i,t} = \propto_0 + \beta_1 CF_{i,t-1} + \beta_2 TDEBT_{i,t-1} + \beta_3 EqIssue_{i,t-1} + \beta_4 OWNCONC_{i,t-1} + \beta_5 AGE_{i,t-1} + \beta_6 SIZE_{i,t-1} + \beta_7 Dcrisis_{08;09} + \mu_{i,t} \quad (2)$$

in which: $u_{i,t} = v_i + e_{i,t}$, v_i are unobserved individual effects. The difference between a pooled OLS and a model that considers individual effects is that the latter takes into consideration the v_i term. The remaining variables have a similar definition and measurement as those presented for Equation (1).

The Lagrange Multiplier (LM) test is used to verify the relevance of the individual effects. The null hypothesis is the non-relevance of unobservable individual effects, while the alternative hypothesis is the relevance of unobservable individual effects. Failing to reject the null hypothesis, it is possible to conclude that the unobservable individual effects are not relevant, and therefore, a pooled OLS is suitable to estimate the parameters of the explanatory variables used. Otherwise, it is concluded that a pooled OLS is not appropriate to estimate the parameters of the explanatory variables used in this study.

If there is no correlation between the unobservable individual effects and explanatory variables, the random effects panel data estimator is more suitable. Otherwise, a panel data model that considers the existence of fixed effects should be used. The Hausman test is used to test the existence of correlation between unobservable individual effects and explanatory variables, where the null hypothesis is the non-existence of that type of correlation, and the alternative hypothesis is the existence of correlation between unobservable individual effects and explanatory variables. If the null hypothesis is rejected, it is concluded that the correlation is relevant, and therefore a panel data estimator considering fixed effects should be used.

This study presents the most suitable panel data model according to the results of the LM and Hausman tests, consistent with the existence of first order autocorrelation.

3.2.2. Dynamic panel data model

Dynamic panel data models allow the use of time series data considering the heterogeneity in adjustment dynamics between different types of firms, due to the dynamic character of the main research variables studied. Therefore, we will use the Generalized Method of Moments (GMM), a dynamic estimator proposed by Blundell and Bond (1998), which allows us to control the endogeneity problem and avoids significant bias in estimates (Wooldridge, 2007). The efficiency of this estimator lies in the possibility of controlling correlation errors over time and heteroscedasticity across firms. The results of the GMM system (1998) estimator can only be valid on the following conditions: (1) validity of the restrictions created using instruments; and (2) there should be no second-order autocorrelation. To test the first condition, i.e., validity of the restrictions created by the instruments used, we use the Hansen test where the null hypothesis is validity of the restrictions created by the instruments used. For the second condition, we test for second-order autocorrelation, where the null hypothesis indicates there is no second-order autocorrelation. In the case of not rejecting the null hypothesis for the Hansen and second-order autocorrelation tests, we conclude that the GMM system (1998) estimator is valid and robust. By using a high number of instruments, the GMM system (1998) estimator leads to major improvements in efficiency compared with the first difference GMM estimator (Arellano and Bover, 1995; Blundell and Bond, 1998). Arellano and Bond (1991), Windmeijer (2005) and Roodman (2006) showed the reliability of the one-step GMM estimator, asymptotically more efficient than the two-step estimator due to the downward biased standard errors. In order to overcome this problem, Windmeijer (2005) developed the small sample corrector, which provides more accurate inference on the two-step procedure especially for the GMM system (1998) estimator (Roodman, 2009). Therefore, we used the two-step procedure with the correction proposed by Windmeijer (2005). To test validity of the instruments used, we resorted to the Hansen test.

GMM system (1998) dynamic estimator is used to estimate the following model:

$$VAIC_{i,t} = \propto_0 + \beta_1 VAIC_{i,t-1} + \beta_2 CF_{i,t-1} + \beta_3 TDEBT_{i,t-1} + \beta_4 EqIssue_{i,t-1} + \beta_5 OWNCONC_{i,t-1} + \beta_6 AGE_{i,t-1} + \beta_7 SIZE_{i,t-1} + \beta_8 Dcrisis_{08;09} + \eta_i + \varepsilon_{i,t} \quad (3)$$

where: η_i are non-observable individual effects and $\varepsilon_{i,t}$ is the error term. The remaining variables have a similar definition and measurement to those presented for Equation (1).

4. Empirical results

4.1. Descriptive statistics and correlation matrix

Table 2 summarizes the descriptive statistics of the dependent and independent variables.

Table 2. Descriptive statistics.

Variables	N	Mean	Median	Standard Deviation
$VAIC_{i,t}$	7474	2.1	2	1.1
$InvIntangible_{i,t}$	9414	0.029	0.0045	0.33
$CF_{i,t}$	9090	0.041	0.077	0.38
$TDEBT_{i,t}$	9414	0.2	0.17	0.17
$EqIssue_{i,t}$	8606	0.044	0	0.25
$OWNCONC_{i,t}$	8813	17	0	23
$SIZE_{i,t}$	9195	12	12	2.1
$AGE_{i,t}$	9414	3.3	3.2	0.99

Note: Intellectual Capital investment ($\mathrm{VAIC_{i,t}}$) Cash Flow($\mathrm{CF_{i,t}}$) Total Debt ($\mathrm{TDEBT_{i,t}}$) Equity issue ($\mathrm{EqIssue_{i,t}}$) Ownership concentration ($\mathrm{OWNCONC_{i,t}}$) Size ($\mathrm{SIZE_{i,t}}$) Age ($\mathrm{AGE_{i,t}}$) Financial Crisis ($\mathrm{Dcrisis_{08;09}}$).

The results presented in Table 2 show that VAIC, the proxy of IC, presents an average of 2.1 and a standard deviation of 1.1, thus this variable does not present a considerable volatility. The average of cash flow is 0.041, the average of equity issues is 0.044 and the average of total leverage is 0.17. Considering that the standard deviation is superior to the average of cash flow and equity issues, we can conclude that these variables present some volatility. Additionally, firms, on average, present a size about €162754.8 thousand and on average, they are 27.1 years old. Regarding the variable ownership, it presents, on average, 17% that corresponds to the percentage of holdings of employees or family members.

The correlation matrix, presented in Table 3, shows the correlation and magnitude of the variables studied.

According to Gujarati and Porter (2010), problems of endogeneity between independent variables are relevant for correlation coefficients above 30%. There are no correlations above 30% among the independent variables.

The Lagrange Multiplier, LM (χ^2), indicates a result of 101.53*** meaning that this result is statistically significant at 1% level and, therefore, we should reject the null hypothesis that the unobservable individual effects are not relevant in the explanation of the dependent variable. Therefore, the pooled OLS regression is not the most appropriate to estimate the results. Also, the Hausman test, Hausman (χ^2), indicates a result of 58.99*** meaning that this result is statistically significant at 1% level and, therefore, we should reject the null hypothesis of the non-existence of correlation between unobservable individual effects and explanatory variables. Therefore, the fixed effects model is the most appropriate to use.

However, static models do not allow analysis of the dynamism of financial choices for IC investment. Therefore, this study uses the GMM system (1998) estimator, which besides the advantages already mentioned, considers the lagged dependent variable, $VAIC_{i,t-1}$. Regarding the GMM system (1998) estimations, the Hansen (χ^2) test is not statistically significant and, therefore, we cannot reject the null hypothesis of the validity of the instruments used. Moreover, the second-order autocorrelation tests, m2 (N(0,1)), is not significant and, therefore, we do not reject the hypothesis of the non-existence of second-order autocorrelation for the estimated models. This being so, the results of the GMM system (1998) dynamic estimator are robust and can support discussion of the results. Therefore, in the following section we discuss the results obtained from using GMM system (1998) estimator.

Table 3. Correlation matrix.

	$VAIC_{i,t}$	$VAIC_{i,t-1}$	$InvIntangible_{i,t}$	$InvIntangible_{i,t-1}$	$CF_{i,t-1}$	$SIZE_{i,t-1}$	$AGE_{i,t-1}$	$EqIssue_{i,t-1}$	$OWNCONC_{i,t-1}$	$TDEBT_{i,t-1}$
$VAIC_{i,t}$	1.0000									
$VAIC_{i,t-1}$	0.6636*	1.0000								
$InvIntangible_{i,t}$	−0.0118	0.0112	1.0000							
$InvIntangible_{i,t-1}$	−0.0314	−0.0269	0.0725*	1.0000						
$CF_{i,t-1}$	0.2366*	0.2621*	0.0398*	−0.0015	1.0000					
$SIZE_{i,t-1}$	0.1164*	0.1342*	−0.0140	−0.0159	0.1476*	1.0000				
$AGE_{i,t-1}$	−0.1014*	−0.0981*	0.0030	0.0060	0.0452*	0.2121*	1.0000			
$EqIssue_{i,t-1}$	−0.0309	−0.0206	−0.0033	−0.0167	−0.2037*	−0.1327*	−0.0678*	1.0000		
$OWNCONC_{i,t-1}$	−0.0919*	−0.0876*	−0.0308**	−0.0070	−0.0121	−0.2284*	−0.0421*	−0.0231	1.0000	
$TDEBT_{i,t-1}$	0.0124	0.0025	−0.0273	−0.0192	−0.1270*	0.2649*	0.0413*	−0.0406*	−0.0242	1.0000

Note: Intellectual Capital investment ($VAIC_{i,t}$) Intangible Assets investment ($InvIntangible_{i,t}$) Cash Flow($CF_{i,t}$) Total Debt ($TDEBT_{i,t}$) Equity issue ($EqIssue_{i,t}$) Ownership concentration ($OWNCONC_{i,t}$) Size ($SIZE_{i,t}$) Age ($AGE_{i,t}$) Financial Crisis ($Dcrisis_{08;09}$) 1. * significant at 1% level.

4.2. GMM system results

The results of the estimated Equation (3) using the GMM system (1998) dynamic estimator are presented in Table 4.

Table 4. Estimation results—VAIC.

	Dependent Variable: $VAIC_{i,t}$			
Independent Variables	Pooled OLS	RE	FE	GMM system (1998)
$VAIC_{i,t-1}$				0.79409***
				(0.05057)
$CF_{i,t-1}$	1.24073***	0.65381***	0.59755***	0.54851**
	(0.09124)	(0.09754)	(0.10917)	(0.19712)
$TDEBT_{i,t-1}$	−0.84957***	−0.71144***	−0.44815***	−0.37700**
	(0.08530)	(0.11799)	(0.14769)	(0.13058)
$EqIssue_{i,t-1}$	0.46048***	0.20930**	0.19777*	0.60002**
	(0.11118)	(0.10167)	(0.10760)	(0.21871)
$OWNCONC_{i,t-1}$	−0.00047	−0.00076	−0.00088	−0.00145**
	(0.00057)	(0.00083)	(0.00103)	(0.00057)
$SIZE_{i,t-1}$	0.02650***	0.00438	0.06989*	0.01597**
	(0.00752)	(0.01413)	(0.03688)	(0.00797)
$AGE_{i,t-1}$	−0.08864***	−0.05423**	−0.10817	−0.09518**
	(0.01363)	(0.02721)	(0.06584)	(0.03868)
$Dcrisis_{08;09}$	−0.10477***	−0.08876***	−0.07065**	−0.12865***
	(0.03350)	(0.02774)	(0.02849)	(0.02316)
CONS	2.15028***	2.35143***	2.67586***	0.62746***
	(0.09804)	(0.18117)	(0.45053)	(0.14663)
Observations	5,771	5,771	5,771	4,731
Firms	766	766	766	722
LM (χ^2)		101.53***		
Hausman (χ^2)		28.94***		
R^2	0.06034	0.0557	0.01277	
Wald (χ^2)		114.39***		
F (*N*(0,1))	52.87***		9.238***	81.39***
Hansen (χ^2)				61.27
m1 (*N*(0,1))				−3.768***
m2 (*N*(0,1))				2.170

Notes: Intellectual Capital investment ($VAIC_{i,t}$) Cash Flow($CF_{i,t}$) Total Debt ($TDEBT_{i,t}$) Equity issue ($EqIssue_{i,t}$) Ownership concentration ($OWNCONC_{i,t}$) Size ($SIZE_{i,t}$) Age ($AGE_{i,t}$) Financial Crisis ($Dcrisis_{08;09}$) 1. CONS is the constant of the regressions. 2. Standard errors in parentheses. 3. ***significant at 1% level, **significant at 5% level and *significant at 10% level.

The results obtained for the relationships between the explanatory variables and $VAIC_{i,t}$ are the following: $VAIC_{i,t-1}$, $CF_{i,t-1}$, $EqIssue_{i,t-1}$, and $SIZE_{i,t-1}$ have positive relationships with $VAIC_{i,t}$; while $TDEBT_{i,t-1}$, $OWNCONC_{i,t-1}$, $AGE_{i,t-1}$, and $Dcrisis_{08;09}$ present negative relationships with $VAIC_{i,t}$.

5. Discussion of the results

Regarding the estimations obtained using system GMM (1998) estimator, for the Equation (4):

$$VAIC_{i,t} = \propto_0 + \beta_1 VAIC_{i,t-1} + \beta_2 CF_{i,t-1} + \beta_3 TDEBT_{i,t-1} + \beta_4 EqIssue_{i,t-1} + \beta_5 OWNCONC_{i,t-1} + \beta_6 AGE_{i,t-1} + \beta_7 SIZE_{i,t-1} + \beta_8 Dcrisis_{08;09} + \eta_i + \varepsilon_{i,t} \quad (4)$$

The results obtained for the relationships between the dependent variable ($VAIC_{i,t}$) and the independent variables $CF_{i,t-1}$, $TDEBT_{i,t-1}$ $EqIssue_{i,t-1}$, $OWNCONC_{i,t-1,}$ $AGE_{i,t-1,}$ $SIZE_{i,t-1}$, and $Dcrisis_{08;09}$ are presented in Table 4. Accordingly, the results suggest that cash flow (i.e., internal finance) and equity issues, in the previous period, present positive relationships with IC in the current period in high-tech firms. However, debt in the previous period has a negative impact on IC in the current period in high-tech firms. The results in Table 4 show that the impact of cash flow and equity issues is 0.55 and 0.6, respectively, while the effect of debt is about −0.38 on high-tech firms IC. These results evidence the positive effect of equity issues and internal finance, while debt has a negative impact of for high-tech firms IC. These results suggest that internal finance and equity issues are the financing choices preferred by high-tech firms to fund IC investment.

The results also suggest that high-tech firms tend to avoid resorting to debt to fund IC. Regarding the results obtained (Appendix A) for the relationships between investment in intangible assets and internal finance, debt and equity issues, it is possible to conclude they are like the results obtained for the relationships between IC and internal finance, debt and equity issues. This corroborates the argument of several authors (Frank and Goyal, 2008; Parsons and Titman, 2009) that firms with high levels of intangible assets tend to have less debt. Moreover, specific, non-redeployable assets, such as IC assets, hinder access to credit on favourable terms (Hall and Lerner, 2010; Magri, 2014), increasing credit costs. Therefore, the results suggest that high-tech firms rely on equity issues and internal finance to fund intangible assets, namely IC assets, to minimize the financial costs. In this context, Berk et al. (2010) identified a negative relationship between intellectual capital and leverage concluding that intellectual capital-intensive firms face greater indirect costs of bankruptcy due to the high costs associated with entrenched employee salaries. Those authors also conclude that firms with high levels of IC investment may face problems of asymmetric information due to the low liquidation value of IC assets. Therefore, these firms prefer internal funds and present lower levels of debt.

Furthermore, high-tech firms' use of internal finance is explained by lower costs, given that internal finance has no problems of asymmetric information. Issuing equity may be expensive due to transaction costs and problems of information asymmetry between firms' insiders and outsiders. However, Lee et al. (2014) state that high-tech investments are difficult to evaluate and involve high risk. Therefore, for these authors equity issues have many advantages over debt to fund high-tech investments, since they do not require collateral and do not increase the probability of firm bankruptcy. Furthermore, issuing equity gives shareholders greater control of managers' opportunistic behaviour. Additionally, several authors (Cronje and Moolman, 2013; Dumay, 2016; Lal Bhasin, 2012; Osinski et al., 2017) argue that when high-tech firms provide detailed, useful information to investors about the sources of firm value creation, information asymmetry diminishes, and thus the cost of equity issues is reduced, and investors' decision-making process is improved.

Thus, the current study seems to reverse the predictions of POT, given that high-tech firms seem to avoid using debt to fund their IC investments, relying on internal finance and equity issues. These results may be due to the problems of asymmetric information high-tech firms face with creditors and consequently poor terms in accessing credit. The results obtained here agree with various studies (Gatchev et al., 2009; Hogan and Hutson, 2005; Magri, 2014; Ferrando and Preuss, 2018). Furthermore, for firms in general, Bolek and Lyroud (2015) conclude that IC influences capital structure, equity issues being the main finance source of IC, while debt presents a negative relationship with IC. However, Lim et al. (2020) found a positive relationship between identifiable intangible assets and debt, but a negative impact of unidentifiable intangible assets on debt level. Liu and Wang (2011), using three patent-based variables as proxies for intellectual capital, found a positive relationship between capital intellectual and debt in high tech firms.

The results obtained provide empirical evidence of the influence of ownership concentration on high-tech firms' IC investments, given that the impact of ownership concentration on high-tech firms' IC investment is about −0.00145 (Table 4). In general, ownership concentration affects negatively IC investments in high-tech firms. This suggests that low ownership concentration brings benefits to the firm, as a more dispersed ownership structure seems to increase IC investment (Burkart et al., 1997; Prendergast, 2002).

Concerning the impact of the 2008–2009 crisis, the results show a negative effect on IC investment. This may be a consequence of the crisis adversely affecting the firm´s capacity to generate positive cash flows, consequently, firms became more dependent on external financing sources. However, during the financial crisis, most European firms faced credit constraints, therefore debt being a restriction as a funding source of investment.

6. Conclusion

This paper seeks to analyse the relationships between high tech firms' financing choices and IC investments. We use data collected from the DataStream database for a research sample of non-financial, listed, high-tech firms in 14 European countries referring to the period between 2004 and 2015.

The results suggest that high-tech firms fund IC investments through internal finance and equity issues. They also suggest that high-tech firms tend to avoid using debt to fund their innovative projects. These results suggest a modified version of pecking order theory. The problems of asymmetric information and agency probably imply unfavourable terms for high-tech firms in accessing to credit. Therefore, these firms choose equity issues and internal finance to fund IC assets. The results also suggest that low ownership concentration in high-tech firms brings benefits as a greater level of ownership concentration impacts negatively on IC investment.

Concerning the impact of the 2008–2009 crisis, there is a negative effect on IC investment, probably due to low capacity in generation internal finance due to the contraction of demand associated with the economic recession. Furthermore, the financial crisis impacted negatively on terms of credit, thus deteriorating the conditions for high-tech firms in accessing to credit to fund IC assets.

The current study presents several contributions. To our knowledge, this is the first study exploring the relationships between IC investment and high-tech firms' financing choices, showing the importance of internal finance and equity issues. Our findings also contribute to the literature by analysing the impact of ownership concentration on high-tech firms' IC investments.

Considering the potential positive impact of IC investments on firm innovative capacity, namely on processes and product development, we suggest managers to devote more attention to the contribution of IC to the generation of financial resources in the firm. For policy-makers, we suggest the need to develop programmes to promote firms' IC investment, since projects requiring relevant amount of capital invested in intangible assets may face obstacles in accessing to credit on favourable terms.

The current study has the following limitations. Countries' characteristics, such as legal aspects, or accounting practices, may influence the results. For future research, we suggest testing the impact of IC on financing choices by comparing results among different European countries. Also, in future research, we suggest the analysis of the relationship between corporate governance variables and IC investments.

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Conflict of interest

The authors declare no conflict of interest.

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