Financing constraints, R&D investments and innovative performances: new empirical evidence at the firm level for Europe.

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Abstract

The relationship between financing constraints, R&D investments and innovative performances has recently attracted renewed attention in the aftermath of a financial crisis that has led to problems of access to the credit on which innovation activities crucially rely. In spite of past developments in the theoretical analysis and in the data and methodologies for empirical investigation, some issues have remained unexplored to date. In this introduction to the special issue we examine the contribution of the papers it contains, which provide new conceptualisations and empirical evidence at the firm level for Europe. Most previous research results, which were mainly based on extending models of financing constraints and physical investments to R&D investments, are confirmed, while new insights about this relationship are uncovered, in terms of the structural characteristics of the constrained firms, of the industries in which they operate, of their innovative activities and of the innovation outcomes they achieve.

Key-words: R&D; financial constraints; innovation.

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1. Introduction

Corporate investments in R&D and innovation have a number of characteristics that make it more difficult to finance than other investments. R&D projects are risky, sometimes radically uncertain, with negative consequences both for their equity financing – as investors discount this uncertainty on financial and stock markets – and for their debt financing – when collateralization becomes prohibitive or even impossible. Furthermore, the problems of opportunistic behaviour, adverse selection and moral hazard affecting the financing of capital investments in general are exacerbated in the case of R&D financing, with respect to which contract incompleteness, opaqueness and information asymmetry between firms and investors are also more pervasisve (Hall and Lerner, 2010). In sum, raising external funds for innovative investments is subject to difficulties that make firms mainly rely on their own internal finance, as in the pecking order theory of Myers and Majluf (1984).

Because of this, financing constraints could end up thwarting profitable R&D investment opportunities when firms fall short of internal funds, leading to a market failure in innovation that adds to that created by the public good nature of R&D knowledge (Hall, 1992). In turn, by dampening R&D investments, financing constraints could be expected to reduce firms' innovative activity and its impact on their economic performance, as opposed to the case of frictionless capital markets (Carpenter and Petersen, 2002; Brown et al., 2009).

While the arguments of a link between financing constraints, R&D investments and innovative performances appear sound and rooted in economic theory, empirical evidence is relatively recent and to date quite mixed although leaning towards finding that the proposed theoretical link exists. On the one hand, whether "financing constraints matter for R&D" (Brown et al., 2012) has been found to be dependent on firms' structural characteristics (size and age, in particular) and R&D financing strategies (internal vs. external), as well as quite variable across different temporal and geographical empirical settings (Himmelberg and Petersen, 1994; Harhoff, 1998; Mulkay et al., 2000; Bond et al., 2005; Cincera and Ravet, 2010; Brown et al., 2012). On the other hand, the "more money, more innovation" story (Hottenrott and Peters, 2012) has also been questioned, by pointing to a possible beneficial impact of financing constraints on the selection of more efficient innovative projects (Musso and Schiavo, 2008; Almeida et al., 2013) – that is, "less money, better innovation" – and to a possible reverse impact of innovation on financing constraints, due to the riskness and information problems the former entails (Hajivassiliou and Savignac, 2007; Hottenrott and Peters, 2012; Lahr and Mina, 2013) – that is, "more innovation, less money".

A similar mismatch between theory and empirics can be found with respect to the policy measures to address the market failure embedded in the relationship between financing constraints, R&D investments and innovative performances: spanning from R&D subsidies to tax incentives, passing through regulatory changes in the fiscal and legal environments to improve the functioning of financial and capital markets (Hervas et al., 2013; Moncada-Paternò-Castello et al., 2014). On the one hand, a typical policy such as an R&D grant may have a multiplier effect, by adding a "certification effect" - the government providing positive signals about the firm's R&D projects - to the more standard "funding effect" - the government turning the net present value of R&D projects from negative to positive (Howell, 2015). On the other hand, empirical evidence on the viability (or "additionality") of these policy schemes, and of R&D subsidy programs in particular, which has increased impressively over time, especially in Europe, has not reached a consensus, and has sometimes found crowding out effects

(e.g.; Busom, 2000; Duguet, 2004; González and Pazó, 2008; Serrano-Velarde, 2008; Czarnitzki and Lopes-Bento, 2012; Blasio, et al., 2014; Henningsen et al., 2015).[1]

However, the 2008-2009 financial crisis followed by economic recession and the sovereign debt crisis, have made the issue at stake relatively more urgent to address than others. Recognition of the fact that this crisis might have hit innovative firms more severely (and young and small firms, in particular) has therefore made the policy actions in response to the crisis relevant for innovation policy (OECD, 2009, 2014). Therefore, in light of this topic academic and policy relevance, a special issue on the link between financing constraints, R&D investments and innovative performance appears very timely. Furthemore, it also represents an important opportunity to take stock of the recent growth in the cross-fertilisation between innovation economics and corporate finance, as well as in the availability of data and the development of analytical models and econometric techniques for the investigation of innovation issues at the firm level.

In spite of its increasing relevance and of the previous body of research in this area, a number of aspects still require closer attention in the analyis of the relationship between R&D, innovation and productivity, in a setting where financial constraints affect these relationships. On the one hand, the distinctive industrial structure of European countries – marked by the dominance of SMEs and a diffuse specialization in low/mid-tech industries – demands more reliable and systematic evidence on the extent to which the causes and the effects of financial constraints in innovation depend on the firms' characteristics and on those of the industries in which they operate. On the other hand, the new economic scenario entailed by the 2008-2009 financial crisis and the new constraints that the sovereign debt crisis poses to economic policy action in Europe require a focus on the different effects of financial constraints along the business cycle and the policy actions to address this issue.

The seven papers of this special issue provide new conceptualization and empirical evidence on both of these areas.[2] What is more, they do so using a wide range of econometric strategies and techniques applied to both established and newly constructed datasets with respect to both individual (i.e. Belgium, Italy, the UK, Sweden), and groups of European countries. Their positioning with respect to the extant literature will be illustrated in Section 2 of this introduction, which presents a first "horizontal" reading of the seven papers, pointing out similarities and differences across them. Section 3 instead contains a "vertical" reading of the same papers, in terms of main research questions and results, while it refers the reader to a synoptic table (Table 1) for their methodological aspects. Section 4 concludes with some policy implications and potential future lines of research to which the papers point.

2. Background literature and positioning of the papers

The papers of this special issue mainly deal with the role of financing constraints. In so doing, they refer to an issue, which has become central in corporate finance since the seminal contribution by Fazzari et al. (1988) about the higher sensitivity of physical investments to cash-flow shocks for

[1] See David et al. (2000) for a seminal survey of additionality results.

[2] These seven papers represent a selection of those presented at 4th European Conference on Corporate R&D and Innovation: "Financing R&D and Innovation for Corporate Growth in the EU: Strategies, Drivers and Barriers" (CONCORDi-2013), organised by the JRC-IPTS of the European Commission in Seville, September, 26-27, 2013 (http://iri.jrc.ec.europa.eu/concord/2013/index.html).

financially constrained firms.[3] In spite of some methodological problems, on which we will return later, this work actually inaugurated a very influential stream of research, in which cash-flows are set at the centre of the identification strategy for financing constraints and financing distress, and conventional investment regressions are used to estimate their impact (Schiantarelli, 1996; Kaplan and Zingales, 1997, 2000; Cleary, 1999).

In both its standard formulations and later refinements, this analytical framework has been able to provide confirmation of financing constraints to physical investments in different contexts (e.g. Hu and Schiantarelli, 1998; Allayannis and Mozumdar, 2004; Almeida and Campello, 2007). Accordingly, although with a certain delay - mainly due to data availability and methodological problems in building up the relevant capital stock - the method has been subsequently extended to R&D and other intangible investments, in search for even stronger financing constraints on a cash-flow basis, as theory predicts (see Section 1).

A number of empirical analyses of the R&D-financing constraints relationship for US and European firms have been carried out during recent years (Hall, 1992; Himmelberg and Petersen, 1994; Harhoff, 1998; Mulkay et al., 2000; Bond et al., 2005; Cincera and Ravet, 2010; Brown et al., 2009; Brown et al., 2012). Several conclusions emerge from these studies: 1) Because of the smoothness of R&D spending within firms, it is usually difficult estimate Euler equation or differenced models with any kind of precision, leading to an absence of results using these methods;[4] 2) Error correction or accelerator models, sometimes estimated using GMM system methods, work better and allow for some within firm persistence of the relationships; 3) R&D adjustments in response to expected cash flow by firms makes it harder to find cash flow impacts; 4) Where there are cash flow effects, they are usually stronger in younger and smaller firms; and 5) The impact of financial constraints on R&D for European firms has probably been changing over time due to changes in financial markets, although the most recent work by Brown et al. (2012) does suggest that they are present primarily for young, small, and non-dividend-paying firms.

i) Financing intangible vs. tangible investments: "taking differences seriously".

Although R&D and other intangible expenditures (e.g. investments in training, design, branding and reputation) have been argued to behave like physical investments in that they create firm capital, albeit intangible (Griliches, 1981; Corrado et al., 2007), the nature of these capitals is inherently diverse, as is their impact on innovation (Montresor and Vezzani, 2014). As summarized earlier, in dealing with financing constraints the focus has been mainly on the differences between tangible and intangible investments in terms of uncertainty, contract incompleteness, information asymmetries, opaqueness and the like. Five of the seven papers of this special issue, those by **Altomonte, Mancusi and Vezzulli**, **Cincera, Ravet, and Veugelers**, **Coad, Pellegrino and Savona**, **Czarnitzki, Hall and Hottenrott**, and **Teirlinck, Neicu and Kelchtermans**, develop the implications of these differences for innovation investment and/or innovation performance.

The recent upturn in the business cycle brought about by the 2008-2009 crisis also requires consideration of the differential response of tangible and intangible investments to changing business

[3] More precisely, Fazzari et al. (1988) compared the differences in the sensitivity of physical investments to cash-flow between a priori identified constrained and unconstrained firms, controlling for their investment opportunities with their (average) Tobin's q ratio. While somewhat controversial (e.g., Kaplan and Zingales, 1997, 2000), the pre-classification of firms into differently constrained subpopulations turned out not to be crucial for detecting financing constraints, which were also found with an alternative switching regression estimation of the Tobin's q investment model by Hu and Schiantarelli (1998).

[4] See Harhoff (1998) and Mulkay et al. (2000) for discussion of this issue.

conditions and increasing uncertainty, in light of differences in their reversibility and adjustment costs. Two out of the seven papers, those by **Bontempi** and **Lööf and Nabavi,** address this last point by including in the analysis the sensitivity of R&D and R&D financing to negative and positive shocks in market demand and in money/credit supply.

ii) "Cash-flows or not cash-flows": direct vs. indirect measures of financing constraints.

While cash-flows have been widely used as a proxy for the presence or absence of financing constraints, this use has been criticised by a number of researchers. After the seminal work by Fazzari et al. (1988), their neglect of the possible endogeneity of cash-flows was critiqued as a serious drawback of the model, along with the absence of controls for external financing sources (Kaplan and Zingales, 1997; Cleary, 1999; Brown et al., 2009; Brown et al., 2012).[5] One solution, advocated by Brown and coauthors, has been to use cash holdings rather than cash flow, on the grounds that this more accurately incorporates R&D smoothing behavior in response to high adjustment costs on the part of firms. More recently, the development and spread of innovation surveys at the company level, in particular the Community Innovation Survey (CIS) of the EU, have offered the use of direct (self-reported) measurements of the presence of financing constraints rather than proxies such as cash-flow sensitivities (e.g. Canepa and Stoneman, 2007; Savignac, 2008; Czarnitzki and Hottenrott, 2011; Lahr and Mina, 2013). While representing an important source of extra-information – such as the distinction between the difficulties of access to finance and the cost of finance – and free from the biases affecting the indirect measures,[6] these direct measures are not free from limitations (Savignac, 2008).

Accordingly, it appears desirable to use both identification strategies, in parallel, or even together. This is reflected in the composition of the current special issue. On the one hand, the papers by **Bontempi**, **Cincera, Ravet, and Veugelers**, **Czarnitzki, Hall and Hottenrott**, and **Lööf and Nabavi** capture financing constraints by using balance-sheet information on cash-flows or other related liquidity indicators (e.g. working capital, cash-holdings, financial leverage), following and adapting the conventional physical investement model. The other three papers instead rely on survey-based information. **Coad, Pellegrino and Savona** proxy financing constraints with CIS questionnaire reports of cost and availability of finance as "factors in constraining innovation activities". As a measure of credit constraints, **Altomonte, Mancusi and Vezzulli** use instead the unsuccessful outcomes of the firms' application for more credit as reported on the (FP7 Program) EFIGE questionnaire.[7] **Teirlinck, Neicu and Kelchtermans** use a measure based on a national survey carried out by the Belgian Science Policy Office; unlike the previous two papers however, their paper follows the evaluation policy literature and captures the incidence of financing constraints indirectly, by looking at the role of tax credits (with or without R&D subsidies) to alleviate them via a Likert scale question about the impact of these instruments.

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[5] In the case of large companies, cash-flows could also be affected by accounting methods and policies about the use of dividends. See the seminal contributions by Jensen and Meckling (1976) and Jensen (1986).

[6] In addition to those deriving from the presence of unobserved firm characteristics, which also drive investment decisions and are thus correlated with the cash-flow variable, other biases are due to random measurement errors, simultaneity between the contemporaneous regressors and the disturbance terms, and endogeneity of the contemporaneous regressors and the past disturbances (weak exogeneity).

[7] Results are however complemented with a robustness check using a cash-flow based indicator proposed by Whited and Wu (2006).

iii) Innovative investment and performance: direct and indirect impacts of financing constraints.

For measurement and other reasons, R&D investment is the innovative activity for which the effect of financing constraints can be detected most directly. However, firms' innovation financing behaviours and constraints are not limited to R&D, but can also affect the other dimensions along which innovation takes place (Fagerberg et al., 2005). In particular, the cost of funds also affects firm innovative performance and output – both intermediate (e.g. patents) and final (e.g. new products, processes and services) – and the economic performance that can be derived from innovation in terms of foreign market penetration and increases in productivity. Indeed, in pursuing innovation firms carry on activities other than R&D, such as the development and/or acquisition of complementary assets (Teece, 1986), the establishment of external collaborations and networking (Ahuja, 2000), and external knowledge sourcing, possibly in an open mode (Chesbrough, 2003). All of these activities involve different costs and different degrees of risk bearing for innovative firms, and are therefore relevant to the demand and supply of their external capital (Mina et al., 2013).

Extending the analysis of the direct R&D impact of financing constraints to their indirect effect on other facets of innovation thus appears extremely important and is reflected in this special issue also. On the one hand, a direct and exclusive focus on R&D investments, such as in **Cincera, Ravet, and Veugelers**, is accompanied by an indirect R&D focus, through the effects of R&D tax credits, in **Teirlinck, Neicu and Kelchtermans**; a parallel focus on R&D and other tangible investments, in **Bontempi**; an R&D focus "augmented" with the signalling role of patents, in **Czarnitzki, Hall and Hottenrott**; a simultaneous focus on R&D, exports and total factor productivity, in **Altomonte, Mancusi and Vezzulli**.

On the other hand, variables other than R&D are considered in investigating the impact of financing constraints on innovation. Intermediate innovation output is often *patents*, which the literature has shown to be affected by financing constraints in several ways, such as in the size-bias of patenting activity (e.g. Scellato, 2007), in the outcome of patent races (e.g. Schroth and Szalay, 2010), and in the economic exploitation of patented inventions (e.g. Luzzi, 2014). In addition to their role of potential reducers of financing constraints, studied in **Czarnitzki, Hall and Hottenrott**, patent applications are used as an indicator of innovation that is possibly affected by financing constraints in **Lööf and Nabavi**. The same study extends the analysis of the effects of financing constraints to new export products; *exports* as an indicator of innovative performance are also considered by **Altomonte, Mancusi and Vezzulli**. This focus on exports is a desirable feature of the special issue, given the mixed arguments and evidence about the role of financing constraints in international trade. They may prevent participation in international markets and reduce firms' level of trade (Manova, 2013), while also being attenuated by international trade because of the easier and more stable access to credit that the status of exporter normally guarantees (Greenaway et al., 2007; Bellone et al., 2010). Finally, **Altomonte, Mancusi and Vezzulli** also consider the relationship between financing constraints and *productivity* (total factor productivity), as do **Coad, Pellegrino and Savona** (labour productivity). Thus this special issue also contributes to filling a gap in the relationship between financing constraints and productivity, which has been largely developed at the macro-level, but mostly overlooked at the firm-level.[8] Indeed, these last two papers suggest that innovation could actually be the missing link between financing constraints and productivity, with the former acting as a barrier

[8] Cross-country studies have actually proliferated following the seminal contribution by King and Levine (1993), about the role of well-developed markets in mobilizing funds for the most efficient investment projects and in diversifying their risks. On the other hand, firm-level studies on this issue are quite a few and affected by some methodological limitations (for a recent survey, see Chen and Guariglia, 2013), that the two papers at stake in the current special issue try also to overcome.

which hampers an efficient allocation of resources towards the most innovative and productive projects.

iv) Variations across sectors and countries, especially within Europe

Financing constraints affect investment and economic performance differently depending on the specific geographical and socio-institutional context, the structural characteristics of the relevant firms, and the economic sectors in which they operate (Dosi, 1990). The first body of work on corporate finance and physical investment centered mainly on large public US firms so these variations were not visible (Jensen, 1986; Fazzari et al., 1988; Brown et al., 2009). Subsequent analysis did find that financing constraints tend to limit investment and growth in smaller US firms (Himmelberg and Petersen, 1994; Carpenter and Petersen, 2002). Similar analyses using European firms had to take into account a somewhat different industrial structure, marked by the dominance of SMEs in most medium-high tech sectors, accompanied by a number of idiosyncratic elements in the functioning of capital markets and financial intermediaries: the quantitative and qualitative deficits of the European venture capital industry; the lower degree of capitalisation of ordinary stock markets and the failures of stock markets directed toward new high technology firms; the general purpose structure of the banking systems and the shortage of high-risk loans (Bottazzi and Da Rin, 2003; Revest and Sapio, 2012).

In the European context, the characteristics of the financing-innovation relationship that may lead to the differences observed (e.g., by Harhoff, 1998 and Mulkay et al., 2000), are that R&D intensities tend to be low, there is a scarcity of internal firm resources for innovation, informal innovation processes are pervasive, and there is extensive knowledge sourcing and networking. All of these features, along with those of the underlying industrial structure, have actually led to the identification of important financial barriers to innovation in Europe, for which a number of R&D and innovation policy initiatives have been devised (e.g. Moncada-Paternò-Castello et al., 2014). In turn, these European policies have attracted a consistent stream of studies on their additionality (e.g. Busom, 2000; Duguet, 2004; González and Pazó, 2008; Serrano-Velarde, 2008; Czarnitzki and Lopes-Bento, 2012; Blasio, et a., 2014; Henningsen et al., 2014), from which financing constraints have been found to be a serious obstacle to innovation. Direct studies of these barriers are more limited, so that the European focus that characterises this special issue – either on invidual European countries (**Bontempi**; **Coad, Pellegrino and Savona**; **Czarnitzki, Hall and Hottenrott**; **Lööf and Nabavi**; **Teirlinck, Neicu and Kelchtermans** or on groups of them (**Altomonte, Mancusi and Vezzulli**; **Cincera, Ravet, and Veugelers)** - appears very timely and desirable, especially in the aftermath of a financial crisis that had a particular impact on Europe and European firms.[9],[10]

While sharing a common focus on Europe, all the papers of this special issue pay particular attention to the source of diversity represented by the structural features of the relevant firms, their *size*, *age*, and the technological intensity of the sectors in which they operate. In one group of papers (**Altomonte, Mancusi and Vezzulli**, **Bontempi**, and **Teirlinck, Neicu and Kelchtermans**), general patterns in the relationships studied are reported after controlling for the heterogeneity of the focal firms and of their industries. In another group of papers (**Czarnitzki, Hall and Hottenrott**, **Cincera,**

[9] As usual, the identity of these individual countries and of their groupings is the combined effect of the authors' research interests and of data availability issues.

[10] The only partial exception is the paper by Cincera, Ravet, and Veugelers (2015, this issue), who carry on a comparison between European and US top R&D investors, using a dataset created by the European Commission (the JRC-IPRS, Scoreboard on Industrial Research and Innovation).

Ravet, and Veugelers, and **Coad, Pellegrino and Savona**), firm size, age and productivity levels emerge as crucial differentiating elements in the results. Finally, the technological level of the relevant industries is a significant conditioning element of the results in **Cincera, Ravet, and Veugelers** and **Lööf and Nabavi**.

Summing up, the "horizontal" reading of the seven papers of this special issue positions them with respect to key issues in the relationship between financing constraints, R&D investments and innovative performance. A transverse view of the papers, such as that synthetised in Table 1, also exhibits heterogeneity among them in terms of datasets, sample characteristics, and econometric methods. Such a richness of methods is accompanied by a richness of interesting and original results, that emerges clearly from the "vertical" reading of the seven papers of the next Section.

[Insert Table 1 here]

3. Summary of results

Table 1 summarizes the specifics of the seven papers in this special issue: the data source(s), the countries and years covered, the type of financing constraint measure, the dependent variables, and the econometric methods used. With this as background, the main results of the seven papers of the special issue are summarised below, following a conceptual order from innovation input to eventual output.

Starting with the impact of financing constraints on R&D investments, **Czarnitzki, Hall and Hottenrott** provide new empirical support (this time for Flemish firms) to their being more harmful for small than large firms, presumably because the former have fewer internal financial resources as well as possibly less access to external sources of funds. These researchers also find novel evidence of the role played by patent applications in attenuating financing constraints to R&D, mainly through a signalling effect with respect to external investors. The impact of patent applications is stronger for small firms, precisely because they face greater financing constraints.

Cincera, Ravet, and Veugelers provide evidence of financing constraints for the leading R&D investors in Europe and the US, which are typically large firms. They find that firm age plays an important differentiating role, which varies with firm nationality and industry. In particular, the European firms created after 1975 in medium and high tech sectors face financing constraints for R&D, while other firms (older, in low tech sectors, or based in the US) do not. This result provides new evidence to help explain the EU-US gap in the innovation realm.

Altomonte, Mancusi and Vezzulli address the relationship between R&D and credit constraints in a novel way, setting it in a simultaneous equations framework that includes their mutual interaction with firm exports and total factor productivity. They do not find direct evidence for the impact of credit constraints on R&D, and they suggest that this relationship is mediated by the positive relationship they find between R&D, on the one hand, and exports and TFP, on the other hand. That is, both exporting and productivity are negatively impacted by credit constraints but positively associated with R&D performance; once they are controlled for there is no credit constraint effect left in the R&D equation.

Bontempi focuses on uncertainty, an important investment characteristic that may affect its sensitivity to financing constraints. Using the model of dynamic R&D investment due to Bloom (2007), she compares R&D and physical investment reactions to an increase in the level of uncertainty. Bloom argues that unlike tangible investment, which is subject to stock adjustment costs, intangible investments should be affected by flow adjustment costs. Her results confirm this prediction and show

that the response of R&D investment in Italian firms to demand shocks is significantly weaker at higher levels of uncertainty, as predicted by the model.

In **Teirlinck, Neicu and Kelchtermans** financing constraints emerge indirectly, through an original analysis of the "combined" additionality of two kinds of policy measures designed to increase firm R&D, an analysis that is based on firm survey responses. The research design of this paper is complex: all firms in the sample received R&D tax credits due to the Flemish R&D credit system, whereas only some of them received subsidies. Four qualitative responses to questions about the impact of tax credits were modelled, comparing those for firms that also had R&D subsidies with those who did not. From this, the additionality of the combination of the two can be inferred. When compared to the counterfactual of tax credits alone, the combination of R&D subsidies with tax credits is found to enable faster research projects, with a more pronounced orientation towards research (versus development) activities. Similar additional effects are also found, though to a lesser extent, in terms of scale and/or number of R&D projects.

Moving to the impact of financing constraints on innovative performance, in **Altomonte, Mancusi and Vezzulli** this appears in the form of a negative correlation between difficulties in accessing credit and firms' exports and TFP. However, these authors also find that European firms desiring credit at their current interest rate and who also have high cash flow and TFP are in fact less likely to ask for and be denied credit. One year later, the same firms still have higher TFP and are more likely to export. This suggests a more complex interrelationship between financing constraints and performance: the most successful firms would like more credit if it were cheap, but are realistic about their prospects and are successful in spite of this, in part because TFP and other firm characteristics are persistent.

In a similar vein, **Lööf and Nabavi** find evidence of a financing constraints impact on patent applications and on new export products, but with variations across different sectors and different phases of the business cycle. Not surprisingly, patents are negatively affected by financing constraints only in high-tech sectors, regardless of the phase of the cycle. On the other hand, the impact of financing constraints on new export products appears negative during economic downturns in medium and low-tech sectors, while it becomes positive during upturns in high-tech sectors.

Coad, Pellegrino and Savona look at the impact of financing constraints and other non-financing barriers on firm labour productivity, using quantile regressions that allow for different impacts at different levels of productivity. Interestingly, both cost and availability of finance are the only type of innovation constraint that emerges as important across the whole productivity distribution, conditioned on size, age, exports, and education level. In contrast, non-financing barriers are either significant for certain quantiles only (e.g., the lack of qualified personnel and information, for the upper half of the productivity distribution) or not significant at all (demand or market structure barriers). Thus this paper supports the idea that financing constraints are the most important obstacle to innovation-related growth outcomes.

4. Conclusions and policy implications

The picture that emerges from these seven studies is not markedly different from that found by previous research, but there are some new nuances. The papers confirm in various ways that financing constraints, whether measured as cash flow or as firm survey responses, do affect the level of R&D investment chosen by European firms negatively, especially if they are more technology-intensive and/or smaller. These constraints can be mitigated by patenting and by underlying firm quality signalled by high TFP or exporting. R&D investment is also discouraged by demand uncertainty (as measured by the variation in firm sales forecasts). In general, the results underline the fact that EU

innovative firms may have problems of credit access, especially in an environment characterized by macroeconomic recession and uncertainty such as the present. However they also contain hints that higher quality firms (proxied as higher TFP, exporting, and more technology-oriented) are able to maintain their activities and productivity in the presence of economic downturns, something that is not surprising on reflection.

A second finding that is not new but contains some interesting detail is that R&D subsidy programs are effective in the presence of R&D tax credits. Flemish firms using both instruments use the additional funds in useful ways, speeding up their projects, directing them more towards research than development (as might be required by the subsidy rules), and increasing their scale and scope. We also have new results on the impact of innovation barriers on productivity which reinforces the view that financial constraints are the most important barriers, although an inability to find qualified personnel and information about innovation also form obstacles for the more productive firms in the UK.

Are there any policy implications from the collection of results here? In our view, the most important may be outside the remit of innovation policy. These are the level of uncertainty in the macro-economic environment and the availability of bank lending which has been constrained by the financial crisis (OECD, 2014). Easing the availability of qualified technical personnel via education and immigration (at least in the UK, where this obstacle was observed) also suggests itself.

Looking specifically at R&D and innovation policy, there already exist a number of instruments in many countries, ranging from targeted R&D subsidies, wage subsidies for scientific and technical personnel, to "patent boxes" for corporate income taxation and broad R&D tax credits. The vast majority of the evidence we have on these instruments is that they are effective in inducing increased R&D.[11] The papers in this special issue make it clear that the firms most in need of policies to reduce their costs of financing are younger smaller firms operating in technology-intensive sectors. However, and especially within Europe, there remains the question of whether R&D tax competition is a zero sum game, as shown for the United States by Wilson (2009) and Bloom et al. (2002) for a set of developed countries. Before introducing any new policy measures, a closer look at this question is warranted.

Further research is also needed in several other areas. First, it would be useful to quantify the impact of financing constraints more precisely, both in relation to their importance as a drag on innovation, which may be minor, and to their further specificities with respect to particular countries. It would be also useful to investigate more thoroughly the costs and benefits both for firms and governments of putting in place different mechanisms for attenuating financial constraints in research and innovation activities. Second, the OECD 2014 SME financing scoreboard reports that a number of countries have introduced loan guarantees, direct lending, and interest rate subsidies to mitigate the effect of the bank credit crisis on SMEs. It would be interesting to know how these instruments affected innovative firms differentially compared to other firms. Given their risk and lack of collateral, such instruments may have been relatively ineffective in alleviating the increased financial constraints created by the crisis for innovation, but this is not a given.

It also emerged that further research is needed on: a) the magnitude, and thus relative importance, of the various external barriers to innovative activities; b) the factors that determine why and when innovative firms are willing (or forced) to take actions to alleviate their financial constraints. For

[11] However, recently Alstadsæter et al. (2015) discussed the dominant tax effects of 'patent boxes' and showed that linking the advantages of 'patent boxes' to the requirement of a real research activity in the country of the patent could mitigate their role as new tax competition tools.

example, to what extent does this depend on the governance structure of the firms? Are there dynamic effects of obtaining informed financing early on?; c) the relation between firm growth and financial constraints: mechanisms and quantitative importance, paying attention to heterogeneity. More generally, there is relatively little knowledge about what makes an organization innovate, which conditions favour the rise of such organizations, and whether certain socio-economic environments and policies can support their development in both manufacturing and service industries.

Finally, the majority of the work in this special issue is essentially cross-sectional, and there were many hints that the performance characteristics of the firms were correlated, even conditional on their broad industry, age, and size (e.g., exporting, patenting, doing R&D, TFP, access to credit even if not enough credit in the firm's view), suggesting that there is a left-out "firm quality" variable. Thus there is a general demand for more and better data to implement analyses that can control for firm differences of this kind. For example, the availability of longitudinal data panels (tracking information on the same subjects at multiple points in time) would be useful in order to introduce a time-series dimension into the econometric setup able to properly assess what exactly the different R&D and/or innovation subsidies for different types of firms entail and what their longer run impacts are. Even more useful is the availability of such data in a form comparable across countries, as in the new OECD micro data initiative. [12]

[12] See http://www.oecd.org/sti/inno/oecdinnovationmicrodataproject.htm and http://www.oecd.org/sti/ind/dynemp.htm for more information on these projects, which aim to have comparable firm micro datasets accessible in each country in a centralized way.

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Table 1 – Synoptic table of the papers

Authors	Title	Country(ies)	Year(s)	Data sources	Sample (main)	Sector	Financing constraints	Dependent variable(s)	Econometric strategy (main)
Dirk Czarnitzki, Bronwyn H. Hall and Hanna Hottenrott	Patents as Quality Signals - The Implications for Financing Constraints on R&D	Belgium	2000-2009 (5 time observations)	Flemish R&D survey; OECD/EPO patent citations database; BEL-FIRST database (Bureau van Dijk)	1,135 firms (4,309 firm-year observations) Unbalanced panel.	R&D-active manufacturing and service sectors	Cash-flow based	R&D intensity	Random effects Tobit model
Michele Cincera, Julien Ravet, Reinhilde Veugelers	The sensitivity of R&D investments to cash flows: Comparing young and old EU and US leading innovators	EU, US	2007-2008	EU Industrial R&D Investment Scoreboard, 2004 - 2008 (JRC-IPTS, European Commission); Compustat (Standard & Poor's).	888 firms (5,989 firm-year observations) Unbalanced panel.	Large R&D-active manufacturing and service sector firms	Cash-flow based	R&D investment	Two-steps GMM difference estimator
Carlo Altomonte, Maria Luisa Mancusi and Andrea Vezzulli	R&D investments, Financing Constraints, Export, and Productivity	France, Germany, Italy, Spain	2010	First survey on European Firms In a Global Economy (EFIGE); Amadeus (Bureau van Dijk).	5,573 firms Cross-section.	Manufacturing	Survey-based and cash-flow based (modified Whited and Wu indicator) as robustness check	Requested credit approved or denied (or W&W indicator); export dummy; R&D dummy; Total Factor Productivity.	Probit; Single equations plus Seemingly Unrelated Regressions (Two stage least squares with instrumental variables as robustness/causality check).
Maria Elena Bontempi	Investment-uncertainty relationship: differences between intangible and physical capital	Italy	2003-2012	Survey on Investment in Manufacturing (Bank of Italy); the Company Accounts Data Service (Centrale dei Bilanci); the National Accounts data (Istat).	15,108 firms (39,159 firm-year observations) Unbalanced panel.	Manufacturing and service sectors	Cash-flow based	R&D and physical investments	Two-steps GMM estimators (difference and system)
Peter Teirlinck, Daniel Neicu and Stijn Kelchtermans	Dipping in the policy mix: do R&D subsidies foster behavioral additionality effects of R&D tax credits?	Belgium	2006-2010	Survey on wage-based R&D tax credit (Belgian Science Policy Office), 2006-2007); BEL-FIRST database (Bureau van Dijk); Federal Public Service Finance (Belgium).	177 firms (treatment group: 105 firms; control group: 72) Cross-section.	R&D tax credit and subsidies using firms	Survey-based (indirectly caught, through tax credit)	Likert scale answer to questions about impact of tax credit	Difference-in-Differences estimation of the treatment effect, complemented by a Probit model

Hans Lööf and Pardis Nabavi	Innovation and credit constraints: Evidence from Swedish exporting firms	Sweden	1997-2007	Audited annual accounts (Statistics Sweden, SCB); Trade statistics (SCB and Swedish Customs); EPO Worldwide Statistical Database, PATSTAT and Swedish patent office.	8,300 firms (2,713 persistent exporters) Unbalanced panel.	Small, manufacturing exporting firms (larger than 10 employees)	Cash-flow based	Patent applications; new product export indicator	Negative Binomial regression
Alex Coad, Gabriele Pellegrino and Maria Savona	Barriers to innovation and firm productivity	UK	2002-2010	UK Community Innovation Survey (UKIS) (Office for National Statistics, Inter-Departmental Business Register).	28,566 firm-year observations	Manufacturing and serivce sectors	Survey-based	Labour productivity	Quantile regression and Propensity Score Matching analysis