The Effects of Macroprudential Policies on Research and Development Expenditure

A System GMM Approach

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Abstract

Preliminary firm level evidence suggests that macroprudential policies reduce firm credit growth and MSME investment, and could therefore have a negative impact on economic growth. However, the question remains if macroprudential policies affect R&D investments as well. Although R&D is primarily financed internally, the literature also suggests that debt financing may be used to some degree depending on firm and country characteristics. Furthermore, implementation of macroprudential policies may also affect R&D indirectly by reducing access to external finance for other investments, compelling firms to deprioritize R&D in their use of internal funds. This study is a first attempt to investigate the effects of borrower–targeted macroprudential policies on research and development expenditures. We estimate a dynamic panel model of R&D financing using a system GMM approach on a heterogeneous sample of European firm level data. Our results indicate that implementation and tightening of borrower–targeted macroprudential policies is associated with lower R&D expenditures for MSMEs and unlisted firms. No evidence is found that these policies affect large and listed firms.

Keywords: macroprudential policy, research and development, economic growth, financial constraints

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1 Introduction

Following the Global Financial Crisis of 2008, policies that seek to enhance system-wide financial stability rapidly became a topic of interest for both policymakers and academics. These macroprudential policies have in effect existed since the 1930's, but had up until 2008 mostly been used in developing economies. Since then, more advanced economies have implemented a broad variety of instruments that the literature has not yet extensively analyzed (Galati and Moessner, 2013). Although efforts have been made to reduce this knowledge gap, the literature is primarily focused on whether the various instruments are effective in achieving their primary goal to reduce procyclicality and structural risks. Relatively little focus has been devoted to investigating their potential externalities.

A welcome exception is the small but growing body of literature on macroprudential policies and growth. However, there is still no consensus among authors on whether there is a positive or negative relationship between the two (Ma, 2020). While some evidence suggests that active use of macroprudential policies enhance growth by reducing economic volatility (Boar et al., 2017), other evidence suggests that they have a negative effect on average growth by restricting economic activity (Sánchez and Röhn, 2016). A study which provides insight of through which channels macroprudential policies can affect growth is a recent paper by Ayyagari et al. (2018). The paper demonstrates that especially borrower-targeted instruments reduce firm credit growth, resulting in a reduction in sales growth and investments of micro, small and medium-sized enterprises (MSMEs).

Since it has been documented that macroprudential policies could negatively affect firm investments, a natural addition to the literature is to investigate which *types* of investments are most affected. Of particular relevance to the relationship between macroprudential policies and growth is whether investment in research and development (R&D) is affected, considering that such activities are an integral part of the growth process. Although R&D is often primarily funded internally (e.g., Hall and Lerner, 2010), evidence suggests that added availability of external finance increases R&D expenditures for smaller firms (Czarnitzki and Hottenrott, 2009) and that bank funding of R&D is especially common in some countries (e.g., Bhagat and Welch, 1995). Moreover, it is possible that macroprudential policies affect R&D indirectly by reducing access to external finance for other investments, compelling firms to deprioritize R&D in their use of internal funds.

This paper contributes to the existing literature on both macroprudential policies and R&D financing by presenting preliminary evidence of the relationship between the two. We empirically analyze data of 2,078 European firms, which differ in both size and listing status, using a system GMM approach. We build upon the dynamic panel model developed by Brown et al. (2012) by including two measures of macroprudential policy implementation and estimating their effects on R&D expenditures. The model is applied to different subsets of our sample, investigating the effects of macroprudential policies on R&D expenditures depending on firm size and listing status. Our results indicate that implementation and tightening of borrower–targeted macroprudential policies are associated with lower R&D expenditures for small and unlisted firms. We find no evidence of these policies affecting the expenditures of large or listed firms.

The structure of the paper proceeds as follows: Section 2 reviews previous research on the effects of macroprudential policies and on R&D financing sources, as well as presents the theoretical framework of this paper. Section 3 presents an overview of the data used in the study. Section 4 explains the methodology of system GMM estimation and presents the specification of our model. Section 5 presents the results, our analysis and two robustness checks. Section 6 concludes the paper and offers suggestions for further research.

2 Previous Literature

2.1 Macroprudential Policies

The purpose of macroprudential policies is to reduce system-wide financial risk, such as interbank exposures and cyclical volatility in credit and asset prices. Since the Global Financial Crisis of 2008, several such policy instruments have been implemented in advanced economies. These can be categorized as either lender– or borrower–targeted, depending on whether they regulate the supply– or demand–side of credit. Common examples of borrower-targeted instruments are loan–to–value (LTV) ratios and debt–to–income (DTI) ratios, which apply to the demand side of credit. Respectively, examples of lender–targeted instruments are caps on foreign currency lending, reserve requirements and ceilings on credit or credit growth, all of which apply to the supply–side of credit (Galati and Moessner, 2013).

As previously mentioned, the body of literature on macroprudential policy instruments is still quite small, although efforts have been made to reduce the knowledge gap. Among the first empirical approaches is Lim et al. (2011), in which the authors perform a cross-country regression analysis of data from 49 countries during 2000-2010 to study the effects of ten macroprudential policy instruments on financial risk. Lim et al. include both borrower and lender targeted instruments in their model, and find that almost all policies (including DTI and LTV ratios) were effective in dampening procyclicality. In another influential study, Cerutti et al. (2017) reach a similar conclusion using an Arellano and Bond (1991) GMM approach on data from 119 countries during 2000-2013. Their results suggest that macroprudential policies are generally associated with a lower credit growth rate for both households and the corporate sector, although most notably for households and in developing and closed economies.

The empirical literature thus suggests that macroprudential policies have been effective in their primary objective to increase financial stability, which in turn has more recently raised questions about their potential impact on economic growth. The reason for this is that studies have shown that other stability-enhancing policies increase growth (e.g., Aghion et al., 2012), indicating that macroprudential policies may have the same effect. One of the first accounts to empirically investigate any potential link between macroprudential policies and growth was Sánchez and Röhn (2016). The authors find that limits on DTI ratios and taxes on financial institutions are negatively correlated with extreme positive and negative growth shocks, while limits on LTV ratios, limits on interbank exposures and taxes on financial institutions are only negatively correlated with extreme positive growth shocks. The authors also find that limits on LTV ratios, limits on interbank exposures and taxes on financial institutions are correlated with lower growth on average (Sánchez and Röhn, 2016). The evidence thus implies a trade-off between stability and growth in the use of such instruments. Conversely, Boar et al. (2017) find no evidence of a trade-off. Using a dynamic GMM approach on panel data for 64 countries over a five–year period, the authors present evidence that intensive use of macroeconomic policies are associated with both higher and less volatile GDP per capita growth rates.

One of the channels through which macroprudential policies can negatively affect growth is through the limitation of financial resources (Boar et al., 2017). This aspect is captured by Ayyagari et al. (2018), who use firm level data to capture the effects of macroprudential policies on firm credit growth and investment. Using data on 900 000 firms in 48 countries during 2003-2011, Ayyagari et al. show that macroeconomic policies reduce firm credit growth, as a consequence of decreased access to bank loans. The magnitude of the effect varied depending on firm characteristics, with smaller and younger firms being relatively more affected. Furthermore, the results were found to be more pronounced when considering borrower-targeted instruments than lender-targeted. Additionally, Ayyagari et al. show that MSMEs experience relatively lower investment and sales growth after implementation of borrower-targeted instruments. The authors contend that these results imply that MSMEs use bank loans as a source of finance for their investments, and that implementation of macroprudential policies reduces access to this debt. This effect is only prevalent for MSMEs because of these firms being more bank dependent and financially constrained, meaning that it is costly and difficult for these firms to fund their activities. Larger firms typically have greater access to both external equity and internal financing, making them less sensitive to such policy changes (Ayyagari et al., 2018).

2.2 R&D Financing

As for all types of investments, firms can finance their R&D activities using internal funds (such as revenue), external funds (such as bank loans) or a combination of the two. Although external financing is an alternative, it has long been recognized that R&D activities have several characteristics that make them more challenging to finance using external sources compared to other investments (Czarnitzki and Hottenrott, 2009). One of these characteristics is that both the main input and output of R&D activities is knowledge, which is an intangible asset. A large part of all R&D expenditures are wages and salaries paid to highly skilled employees, and the main output of their efforts is firm-specific knowledge on how to produce new goods and services (Hall and Lerner, 2010). Therefore, R&D activities rarely involve assets that can be used as collateral for loans, which increases the risk of lending for potential creditors (Müller and Zimmermann, 2006). Moreover, since this intangible asset is partly embedded in the employees, it is lost if they leave the firm. Therefore, firms tend to smooth their R&D expenditures over time in order to avoid lay–offs. R&D spending thus exhibits high adjustment costs, and the required rate of return to such an investment can be high in order to cover them (Hall and Lerner, 2010). Another distinguishing characteristic is the high degree of uncertainty regarding the output value of R&D activities. R&D is often a high risk – high reward type of investment, and the quality of a proposed project can be difficult to evaluate for lenders due to the often highly technical nature of such projects (Ughetto, 2008). This property generates a problem of asymmetric information, which is exacerbated by the fact that firms often wish to keep their research projects as secret as possible due to the risk of imitating competitors. Furthermore, even if a R&D project is successful, lenders are unable to participate in the potentially large rewards since external credit typically comes at a fixed, predetermined interest rate.

Because of the above-listed reasons, access to external financing is typically believed to be more restrictive for R&D than for other types of investments. Consequentially, internal financing is expected to be the preferred option (Howe and McFetridge, 1976; Wang et al., 2016). With the background of internal funds being the primary source of R&D financing, the literature on R&D financing has devoted much attention to detecting constraints due to lacking internal funds (Czarnitzki and Hottenrott, 2009). A common approach to empirically test for financial constraints is to estimate the sensitivity of R&D to cash flow, a method originally developed by Fazzari et al. (1988). The rationale behind this approach is that if a firm responds to an increase in liquidity by increasing investments, there must have been investment opportunities available to the firm before the increase which it chose not to act on. In other words, the firm is assumed not to have been liquid enough to undertake the investment before the increase, and either have chosen to refrain from using external capital or been unable to do so. In these situations, the investment decision is made subject to financial constraints (Hall and Lerner, 2010).

However, as pointed out in Brown et al. (2012), the empirical literature on R&D cash flow sensitivities contains highly mixed results. For example, it has often been noted that there are differences in cash flow sensitivities across firms of different sizes and maturity. Small and young firms have been shown to typically exhibit greater cash flow sensitivities than large and mature firms. Harhoff (1998) presents evidence of such a difference for a diverse sample of German firms during 1990–1994. Using an accelerator model, an error-correction model and a dynamic panel model derived from a Euler equation for investment, Harhoff finds that small firms exhibit cash flow sensitivities, but that such an effect is weak or non–existent for large firms. Similarly, Brown et al. (2012) estimate these effects using a dynamic panel model on a large sample of European firms during 1995–2007. Brown et al. find that even when controlling for R&D smoothing and revenues from issuing external equity, cash flow sensitivities were only detected for relatively small firms in the sample. A viable explanation for differences in cash flow sensitivities across firm size and maturity is that the above–mentioned challenges of external finance for R&D investment are exacerbated for small and young firms. These groups typically have less assets to offer as collateral, information asymmetries are generally larger, and there is a heightened risk of default for young firms. An implication of the aforementioned circumstances is that these firms have limited access to bank loans (Czarnitzki and Hottenrott, 2009). The results are also consistent with the more general literature on investment theory, which, as mentioned in the previous section, suggests that small and young firms are generally more financially constrained (Ayyagari et al., 2018).

Furthermore, differences in cash flow sensitivities have also been noted across countries, or more specifically, across financial market regimes. The literature often focuses on differences between market– and bank–based economies. Countries including the United States, the United Kingdom and Sweden are characterized as being market–based, implying highly developed stock markets and advanced venture capital industries. Conversely, bank-based countries such as Italy, Germany and France have a larger focus on debt financing and bank intermediation (Hall and Lerner, 2010). Because of the use of more external financing in market-based economies, firms in these countries have been shown to be more sensitive to fluctuations in cash flow. For example, Bond et al. (2005) use a dynamic panel model on data from large manufacturing firms in the U.K. and Germany and find that while U.K. firms exhibit cash flow sensitivities, German firms did not. Similarly, Mulkay et al. (2001) use an error–correction model on data from large manufacturing firms in France and the U.S. and find that cash flow sensitivities were much larger in France. Across the dimension of financial market regimes, differences of firm size and age persist. Ughetto (2008) uses a difference–GMM approach on a diverse sample of Italian firms and finds that the cash flow–investment elasticity is significantly higher for small firms than medium-sized and large. One interpretation of these results is that firms in bank–based economies are less financially constrained because they have access to bank loans, while firms in market-based economies do not (Czarnitzki and Hottenrott, 2009).

An alternative strategy used for studying R&D financing is to investigate the relationship between firms' financial structure and R&D performance. Although differing in methodology, the results of such studies are highly similar to those that estimate cash flow sensitivities. For example, Bhagat and Welch (1995) provide evidence of this using a cross-sectional VAR method on a sample of American, Canadian, European and Japanese firms during 1985–1990. Bhagat and Welch find that leverage has a positive impact on R&D expenditures in Japan, which is another bank–based economy, but a negative impact in the market–based United States. Similarly, Lucey and Bhaird (2006) find no relationship between leverage and R&D intensity for MSMEs in Ireland. Much like in the literature on cash flow sensitivities, these results imply that firms in bank–based economies have larger access to bank loans for their R&D activities. Moreover, the literature suggests that the more R&D intensive a firm is, the less it is leveraged. For example, Aghion et al. (2004) find that leverage decreases as R&D intensity increases for a sample of listed U.K. firms. Evidence of the relationship between financial structures and R&D shows that all though leverage decreases with R&D intensity, R&D intensive firms are, in fact, leveraged. The results thus indicate that firms may use debt as a source of finance for their R&D, and at the very least show that R&D performing firms use debt for other activities. Furthermore, the literature suggests that this is not only true for large firms or firms in bank–based countries, but for MSMEs and firms in market–based economies as well. Further evidence in support of this can be found in Czarnitzki and Hottenrott (2009), in which the authors use a measure of credit rating to show that access to external funds has a positive impact on R&D intensity for German firms, especially smaller and younger ones.

Moreover, capital structure is related to another important part of R&D financing – the role of external equity. As is the case with debt, issuing equity is costly and tends to be associated with problems of asymmetric information when considering R&D activities (Hall and Lerner, 2010). However, raising funds through issuance of equity can have several advantages over debt; firms do not have to use assets as collateral and investors can share the potentially large profits from a successful project (Brown et al., 2012). Consequently, recent accounts have provided evidence that issuing equity can be an important part of R&D financing, especially for small and young firms. Brown et al. (2012) show that net proceeds from stock issuance have a large and significant impact on R&D expenditures in his sample of European firms, especially so for young and relatively small firms. Similarly, Magri (2014) provides evidence that issuing equity significantly increases the probability that firms invest in R&D, most notably for small, young, and heavily leveraged firms.

2.3 Theoretical Framework

The purpose of this paper is to investigate the effects of macroprudential policies on R&D expenditures. To the best of our knowledge, no similar study has yet been produced on this topic, and so there is little theoretical precedent for a potential relationship between the two. However, as can be understood from the separate bodies of literature on macroprudential policies and R&D financing, it is evident that: (i) borrower-targeted macroprudential policies reduce both firm credit growth and investment, (ii) although firms primarily rely on internal finance for their R&D investments, firms also make use of debt finance either specifically for their R&D investments or for other activities, and (iii), the use of external finance appears to vary across firm size, maturity and country.

The combination of these results suggests that there could be some degree to which macroprudential policies affect R&D investment. However, this effect may be smaller for R&D expenditure than other types of investments due to debt being a disfavored source of financing for R&D activities. We propose that the impact can be either direct or indirect, depending on whether debt finance is used specifically for R&D activities or for other investments. If indirect, use of macroprudential policies imposes or intensifies financial constraints on the investment that debt is used for, thereby compelling firms to substitute use of debt with internal funds. Since internal funds are limited, firms will need to prioritize their use of them and possibly choose to reduce R&D spending.

Building upon the results in Ayyagari et al. (2018) and Czarnitzki and Hottenrott (2009), we expect that this relationship primarily holds for younger and smaller firms, and only for borrower–targeted macroprudential policies. As argued by Ayyagari et al. (2018), these firms are already financially constrained, and restricting their access to one source of finance would therefore exacerbate this circumstance. Since Czarnitzki and Hottenrott (2009) show that improving the access to debt has the largest effect on R&D expenditures for small and young firms, we suspect the opposite will hold in the case of restrictions. However, due to limited data availability, the scope of this study is restricted to differences in size and not maturity. Furthermore, the results of Ayyagari et al. were most conclusive for the borrower-targeted instruments LTV and DSTI ratios, which is expected since these instruments directly correspond to the firms' supply of assets and stream of cash flow. Consequentially, this paper will be restricted to the study of these specific instruments.

Additionally, we suspect that the effects of macroprudential policy implementations on R&D expenditures will be larger for firms that are not listed on a stock market than those that are. As discussed in the previous section, evidence suggests that issuing equity can be an important part of R&D financing, especially for smaller and younger firms. Therefore, firms that raise funds through equity are expected to be less dependent on bank loans than those that are not.

3 Data

Our sample consists of data of 2,078 firms from 14 countries from the European Union and the United Kingdom between 2013-2020.[1] The EU and the UK have been chosen for two reasons: (i) to estimate the effect of macroprudential policies on R&D expenditures, this study will largely build upon Brown et al. (2012) who made the same selection (ii) the countries in the sample have been relatively active in macroprudential policy implementation during this time period. The added limitation to the specific 14 countries has been made due to data availability, with countries who contributed less than 3 firms in the baseline regression having been removed. In accordance with previous literature on R&D financing, only manufacturing firms (with SIC codes between 2999-4000) have been included.[2] Furthermore, only firms which reported positive spending on research and development for 2016-2018 have been included. This restriction is partly due to Brown et al. (2012) only including firms with three consecutive years of data, but also to minimize gaps in the data.

Following Brown et al. (2012), several financial variables that determine R&D expenditures have been controlled for in the regression. Data on financial variables have been collected from Orbis (2022), a worldwide private company database. Besides R&D expenditures, these are: cash flow, cash holdings, operational revenue[3] and stock issues. Cash flow is calculated gross of R&D expenditures and total depreciation, as specified in Brown et al.[4] Cash holdings are measured as cash and equivalents at end of year. Stock issues denote the net proceeds from stock issuance each year. Variables have been scaled by total assets and winsorized at the 1% level, which is comparable to the 1% trimming of tails that was used in Brown et al. (2012). Summary statistics of the data are presented in Table 3.1.

[1] A list of included countries and their number of firms can be found in the Appendix.

[2] Manufacturing firms have been shown to be the most research intense, and is the focus of the most literature on determinants of R&D expenditure (Brown et al., 2012; Ughetto, 2008; Hall, 1992; Hall and Lerner, 2001)

[3] Brown et al. controlled for sales and not operational revenue, but since many firms lack reporting of sales in our Orbis sample, operational revenue has been used as a proxy.

[4] Extraordinary items are not included in the cash flow calculation because of low data availability for the majority of firms.

Table 3.1: Sample Summary Statistics

Variable	Median	Mean	Observations
Employees	233.00	5,018.19	27,704
R&D Expenditure	0.02	0.05	23,630
Operational Revenue	1.06	1.20	27,367
Cash Holdings	0.08	0.14	26,109
Stock Issues	0.00	0.05	4,779
Cash Flow	0.13	0.14	27,255
Index for Borrowing Targeted Policies	1.00	0.78	28,760
Changes in Borrowing Targeted Policies	1.00	1.01	28,760

All financial variables are scaled by total assets

Data on macroprudential policies have been collected from the IMF's integrated Macroprudential Policy (iMaPP) database, originally constructed by Alam et al. (2019). As previously described, only the borrower-targeted policies LTV and DSTI will be analyzed. LTV describes limits on loan-to-value ratios applied to residential and commercial mortgages. DSTI captures policies limiting the debt-service-to-income and loan-to-income ratio which restrict the size of debt service payments or a loan relative to income. Instead of estimating the individual impacts of these instruments, we follow Ayyagari et al. (2018) by constructing a borrower-targeted index containing information on both of them. This index will in turn be specified in two ways. The first is coded as 0, 1 or 2, indicating if none, either or both of the borrower-targeted instruments were in place in a specific country at a specific time. The second index is a measure of changes in borrower–targeted policies, and contains information on whether or not an instrument has become tightened (stricter) or loosened (less strict) in a specific year.

4 Method

4.1 The GMM System Estimator

To investigate the relationship between borrower–targeted policies and R&D expenditure, we build upon the dynamic panel model used in Brown et al. (2012). The general idea behind dynamic panel models is that there is serial correlation in the dependent variable, such that past values can be used as predictors for current values (Roodman, 2009). This assumption is reasonable when modeling R&D expenditures since they are believed to be highly persistent over time due to expenditure smoothing (Hall and Lerner, 2010). However, using lagged values of the dependent variable as predictors also implies some problems that should be addressed. The main concern is dynamic panel bias, emanating from the additional assumption that there are fixed individual effects in the model that are correlated with the dependent variable. Under this assumption, using lagged values of the dependent variable as regressors implies that there will be correlation between these regressors and the firm–specific effects. This violates the exogeneity condition, meaning that OLS estimators will be inconsistent for dynamic panel models. The problem of endogeneity still holds even when controlling for firm-specific effects using the Least Square Dummy Variable (LSDV) estimator (Roodman, 2009).

An approach which resolves these issues is system GMM estimaton, developed in Arellano and Bover (1995) and Blundell and Bond (1998). It builds on the approach by Arellano and Bond (1991), which is to transform the data to remove the individual fixed effects. The standard transformation is the first-difference one, in which the data matrices are left–multiplied with a matrix $I_N M_D$, where I_N is the identity matrix of order N (the number of individuals in the sample) and M_D is a diagonal matrix of -1s with a subdiagonal of 1s to the right. Performing this transformation removes the time invariant fixed effects in the error term since they are the same in each period (Roodman, 2009). This method can be illustrated with a simple model in which the lagged dependent variable is the only regressor and the error term consists of individual fixed effects and an idiosyncratic term:

$$y_{i,t} = \beta y_{i,t-1} + \varepsilon_{i,t}$$
$$\varepsilon_{i,t} = \alpha_i + v_{i,t}$$

After left-multiplying in matrix form, we obtain:

$$y_{i,t} - y_{i,t-1} = y_{i,t-1} - y_{i,t-2} + \alpha_i - \alpha_i + v_{i,t} - v_{i,t-1}$$
$$\Delta y_{i,t} = \beta \Delta y_{i,t-1} + \Delta v_{i,t}$$

While this transformation removes the individual fixed effects, the idiosyncratic error term and the lagged dependent variable are correlated through the $t-1$ terms. The solution to this problem is to use instruments for the lagged dependent variable. Conveniently, because of the assumption that there is serial correlation in the dependent variable, lagged values of the regressor constitute strong instruments while also eliminating the endogeneity (Roodman, 2009). Estimation is then performed using simple GMM. For the sake of simplicity, the above explanation considers an equation in which the lagged dependent variable is the only regressor in the model. The same principles still apply when adding more endogenous regressors.

Although the first–difference approach eliminates the individual fixed effects, it comes at the cost of magnifying gaps in the data. For example, if there is a missing value in an observation at t, using differences means that the observation will be dropped at both t and $t-1$. Therefore, the differences approach exacerbates problems associated with an unbalanced panel (Roodman, 2009). Since the data used in this study produces an unbalanced panel, the alternative of orthogonal transformation will be used instead. This is another common approach which involves subtracting the average of all future available values instead of taking the first difference, such that:

$$\sqrt{T_{it}/\left(T_{it}+1\right)}(y_{i,t} - 1/T_{it} \textstyle\sum_{s<t} y_{i,s})$$

Where T_{it} is the number of available future observations and $\sqrt{T_{it}/\left(T_{it}+1\right)}$ is a scale factor. This strategy also removes the fixed effects since they are constant, meaning that average of all future fixed effects is equal to the contemporaneous fixed effect. However, as in the case with the first-difference transformation, there might still be endogeneity in the data due to inclusion of same-period values of the regressor and the idiosyncratic error term in the equation. Therefore, lagged values must still be used as instruments and estimation is done using GMM.

Arellano and Bover (1995) and Blundell and Bond (1998) discovered efficiency can be increased further by combining the strategy of data–transformation with another one. Their idea was to purge fixed effects by first–differencing the *instruments* to make them exogenous, rather than first–differencing (or in another way transforming) the data. Instead of instrumenting the transformed variables with untransformed variables, Blundell and Bond instrument untransformed variables with transformed variables. This approach is valid under the additional assumption that first-differenced instruments are exogenous.

The two approaches are combined by adding the untransformed observations to transformed observations in each individual's data. This is done by left-multiplying the dataset by an augmented transformation matrix $M^+ = (M, I)'$ where M is the diagonal matrix used to transform the data. As for the instrument matrix, both transformed and untransformed instruments will now be included, and transformed instruments are used to estimate the untransformed observations and vice versa. Therefore, untransformed instruments are set to zero for untransformed observations and transformed instruments are set to zero for transformed observations (Roodman, 2009).

4.2 Specifying the Model

To explore the effects of macroprudential policies on R&D expenditure, we build upon the dynamic investment model developed by Brown et al. (2012). The model is based on the Euler equation for optimal capital accumulation under imperfect competition, which was originally presented by Bond and Meghir (1994). Their model is specified as:

$$\begin{aligned} Investment_{i,t} =& \beta_1 Investment_{i,t-1} + \beta_2 Investment^2_{i,t-1} + \beta_3 CashFlow_{i,t-1} + \\ & \beta_4 Output_{i,t-1} + \beta_5 Debt^2_{j,t-1} + \beta_9 \Delta CashHoldings_{j,t} + d_t + \alpha_j + v_{j,t} \end{aligned} \tag{1}$$

Where d_t is a time-specific effect, α_j is a firm-specific effect and $v_{j,t}$ is the idiosyncratic error term. All variables are scaled by capital stock. The main contribution of Brown et al. (2012) was to add contemporaneous and lagged cash holdings in order to control for the use of cash to smooth R&D expenditures over time, as discussed in the previous section. Furthermore, Brown et al. found no evidence of a significance of debt issuance in their sample, so the debt term was deleted from the model. Brown et al. also added

Tobin's Q as an additional control for investment demand, proxied output with total sales and included contemporaneous versions of stock issuance and cash flow, leading to their final model:

$$\begin{aligned} RD_{j,t} =& \beta_1 RD_{j,t-1} + \beta_2 RD^2_{j,t-1} + \beta_3 Q_{j,t} + \beta_4 Sales_{j,t-1} + \beta_5 CashFlow_{j,t} + \\ & \beta_6 CashFlow_{j,t-1} + \beta_7 StkIssues_{j,t} + \beta_8 StkIssues_{j,t-1} + \\ & \beta_9 \Delta CashHoldings_{j,t} + \beta_{10} \Delta CashHoldings_{j,t-1} + d_t + \alpha_j + v_{j,t} \end{aligned} \tag{2}$$

where all variables are scaled by beginning of term total assets. Equation (2) is the starting point for the main specification of this paper, and will be used as a baseline for R&D determinants.[5] However, due to data availability, Tobin's Q is omitted from the final specification.[6] Orbis data on this variable is mainly available for very large and listed companies, and this paper will consider slightly smaller firms and include both listed and unlisted firms. Similarly, when performing estimations for the entire sample, we will also omit stock issuance since only listed firms would be included in the regression otherwise. Stock issues are included again when we estimate the model for listed firms only.

Our extension of Equation (2) is to add borrower-targeted macroprudential policies. As described in Section 3, this variable will be specified in two different ways. In Equation (3), the variable is denoted by BOR and is specified as an index describing the number of borrower-targeted policies that were in place in a specific country in a given year. In equation (4), the variable denoted by ΔBOR2 indicates if a policy tightening or loosening has taken place in a given year. Following Ayyagari et al. (2018) the variable is lagged one period in both specifications, since the effect of the policies is expected to be delayed.

[5] As a robustness check, results will be compared to Brown et al. (2012) in Section 5.5 using more similar sample specification.

[6] Omitting Tobin's Q could have biased our results. To investigate this, we used sales growth as a proxy for Tobin's Q (which was also used as a robustness check in Brown et al., 2012) which did not have a significant impact on our results.

$$
\begin{aligned}
RD_{j,t} =& \beta_1 RD_{j,t-1} + \beta_2 RD^2_{j,t-1} + \beta_3 OpRevenue_{j,t-1} + \beta_4 CashFlow_{j,t} + \\
& \beta_5 CashFlow_{j,t-1} + \beta_6 StkIssues_{j,t} + \beta_7 StkIssues_{j,t-1} + \\
& \beta_8 \Delta CashHoldings_{j,t} + \beta_9 \Delta CashHoldings_{j,t-1} + \\
& \beta_{10} BOR_{j,t-1} + d_t + \alpha_j + v_{j,t}
\end{aligned} \tag{3}
$$

$$
\begin{aligned}
RD_{j,t} =& \beta_1 RD_{j,t-1} + \beta_2 RD^2_{j,t-1} + \beta_3 OpRevenue_{j,t-1} + \beta_4 CashFlow_{j,t} + \\
& \beta_5 CashFlow_{j,t-1} + \beta_6 StkIssues_{j,t} + \beta_7 StkIssues_{j,t-1} + \\
& \beta_8 \Delta CashHoldings_{j,t} + \beta_9 \Delta CashHoldings_{j,t-1} + \\
& \beta_{10} \Delta BOR2_{j,t-1} + d_t + \alpha_j + v_{j,t}
\end{aligned} \tag{4}
$$

Following Brown et al. (2012), all financial variables are assumed to be endogenous and are instrumented using their lagged values. This is a reasonable assumption given that operating revenue, cash flow, stock issuance and cash holdings should all be correlated with firm-specific effects. Unlike in Brown et al., 1–2 lags are used as instruments for the transformed equation and one period lags are used as instruments for the untransformed equation.[7]

Unlike the financial variables, the borrower-targeted macroprudential policy variables should not be correlated with firm-specific effects and are thus assumed to be exogenous. Therefore, these variables will instrument themselves and their coefficients are estimated using the IV-estimator.[8] Robust standard errors are used to account for heteroscedasticity. Furthermore, year variables are included as dummies since the robustness and autocorrelation tests assume no correlation across individuals in the idiosyncratic disturbances, and the dummies control for the correlation that is expected to prevail (Roodman, 2009).

[7] Brown et al. (2012) uses lagged levels of $t-3$ and $t-4$ as instruments for the transformed regression, and lags dated $t-4$ for the untransformed regression.

[8] Instruments have been chosen according to results from the AR1, AR2 and Hansen–J tests. The instruments used are assumed to be valid when the p–value for the AR1 test is rejected and the AR2 and Hansen–J tests are not rejected.

5 Results and Analysis

5.1 Results for All Firms

The estimation results for all firms in our sample are reported in Table 5.1. Following Brown et al. (2012), variables have been sequentially added to the specification. Column 1 reports the estimation results without controlling for ΔCashHoldnings, and Column 2 reports the results when doing so. Our contribution – the results of adding macroprudential policy variables – are reported in columns 3 and 4 when controlling for all financial variables. This step-wise inclusion will allow us to compare the results of different specifications.

Table 5.1: Results for All Firms

	(1)	(2)	(3)	(4)
RD_{t-1}	0.635***	0.657***	0.659***	0.654***
	(0.111)	(0.131)	(0.131)	(0.132)
RD^2_{t-1}	-0.0525	0.0276	0.0219	0.0298
	(0.280)	(0.284)	(0.283)	(0.285)
$OpRevenue_{t-1}$	-0.00423*	-0.00492	-0.00500	-0.00497
	(0.00255)	(0.00305)	(0.00307)	(0.00305)
CashFlow	0.0533***	0.0595***	0.0594***	0.0597***
	(0.00854)	(0.0105)	(0.0105)	(0.0105)
$CashFlow_{t-1}$	-0.0170***	-0.0158**	-0.0159**	-0.0156**
	(0.00658)	(0.00776)	(0.00776)	(0.00777)
△CashHoldings		-0.0301***	-0.0301***	-0.0300***
		(0.00595)	(0.00594)	(0.00596)
$\triangle CashHoldings_{t-1}$		0.00324	0.00329	0.00327
		(0.00637)	(0.00637)	(0.00637)
BOR_{t-1}			0.000402	
			(0.000993)	
$\triangle BOR2_{t-1}$				-0.00115
				(0.00115)
Observations	11130	8973	8973	8973
Firms	2078	1982	1982	1982
No. of instruments	21	25	26	26
AR1 (p-value)	0.000	0.000	0.000	0.000
AR2 (p-value)	0.202	0.335	0.335	0.335
Hansen-J (p-value)	0.0623	0.0918	0.0926	0.0954

Standard errors in parentheses
* p<0.10, $**p<0.05$, $***p<0.010$

The coefficient for the lag of RD is relatively large and significant at the 1 percent level for every specification, and becomes slightly larger when including lagged and contemporaneous ΔCashHoldnings and BOR. The lag of RD^2 is insignificant in all specifications. The effect of lagged OpRevenue is significant at the 10 percent level in Column 1 and is insignificant in the other specifications. CashFlow is positive and significant at the 1 percent level for all specifications, with a slightly larger coefficient when including lagged and contemporaneous ΔCashHoldnings and larger so when including ΔBOR2. Lagged CashFlow is negative and small in absolute value with a 1 percent significance level in Column 1. In the specifications that include lagged and contemporaneous ΔCashHoldnings, it is significant at the 5 percent level with a slightly less negative coefficient. ΔCashHoldnings has a negative coefficient which is significant at the 1 percent level in all specifications where it is included, and remains largely unchanged by including BOR or ΔBOR2. The lag of ΔCashHoldnings is insignificant in all specifications. Neither BOR nor ΔBOR2 are significant at any conventional level, and coefficients of both variables are negligible.

5.2 Results for Size Classifications

Table 5.2 presents the estimation results when dividing the sample into categories according to size classification.[9] As in 5.1, variables are added sequentially. The results for MSMEs are reported in columns 1–4 and follow a similar pattern to the results for all firms. The lag of RD continues to be significant at the 1 percent level, although becomes smaller when including lagged and contemporaneous ΔCashHoldnings. The coefficients for lagged RD are smaller for MSMEs than for all firms (0.561 in Column 2 compared to 0.657). The lag of RD^2 continues to be insignificant. OpRevenue is significant at the 10 percent level for all MSME specifications, with negative coefficients which are small in absolute values. CashFlow is positive and significant at the 1 percent level in all specifications, and becomes slightly larger when controlling for lagged and contemporaneous ΔCashHoldnings. Lagged CashFlow continues to be negative, and becomes less significant (from the 5 to 10 percent level) when including cash holdings in the specification. ΔCashHoldnings is negative and significant at the 1 percent level, and has similar values in regression with and without controlling for BOR and ΔBOR2. The most important distinction from when estimating for all firms is that the coefficient for BOR is negative and significant at the 10 percent level. ΔBOR2 remains insignificant in all specifications.

[9] MSMEs are defined as firms with 249 or fewer employees and large firms are defined as those with 250 or more employees. Firms which have not reported the number of employees are classified according to turnover based on the convention of the European Commission Communication.

Table 5.2: Results for SMEs and Large Firms

	MSMEs				Large Firms			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
RD_{t-1}	0.646***	0.561***	0.560***	0.560***	0.770***	0.896***	0.898***	0.896***
	(0.134)	(0.153)	(0.153)	(0.152)	(0.155)	(0.169)	(0.170)	(0.168)
RD^2_{t-1}	-0.0670	0.243	0.243	0.246	-0.380	-0.573	-0.577	-0.573
	(0.286)	(0.310)	(0.308)	(0.310)	(0.490)	(0.431)	(0.431)	(0.430)
$OpRevenue_{t-1}$	-0.00546*	-0.00596*	-0.00593*	-0.00597*	-0.00395	-0.00288	-0.00301	-0.00293
	(0.00322)	(0.00355)	(0.00353)	(0.00355)	(0.00374)	(0.00498)	(0.00503)	(0.00502)
CashFlow	0.0523***	0.0612***	0.0612***	0.0611***	0.0323***	0.0330**	0.0330**	0.0331**
	(0.00996)	(0.0124)	(0.0124)	(0.0124)	(0.0113)	(0.0129)	(0.0129)	(0.0129)
$CashFlow_{t-1}$	-0.0170**	-0.0177*	-0.0173*	-0.0177*	-0.0144	-0.00401	-0.00393	-0.00402
	(0.00821)	(0.0101)	(0.0102)	(0.0101)	(0.00903)	(0.00950)	(0.00947)	(0.00950)
$\triangle$CashHoldings		-0.0313***	-0.0313***	-0.0312***		-0.0280***	-0.0280***	-0.0280***
		(0.00811)	(0.00812)	(0.00814)		(0.00768)	(0.00767)	(0.00766)
$\triangle CashHoldings_{t-1}$		0.00696	0.00676	0.00708		-0.0100	-0.00999	-0.0100
		(0.00897)	(0.00899)	(0.00897)		(0.00720)	(0.00719)	(0.00721)
BOR_{t-1}			-0.00749*				0.000428	
			(0.00447)				(0.00110)	
$\triangle BOR2_{t-1}$				-0.00189				0.0000815
				(0.00551)				(0.000892)
Observations	4810	3827	3827	3827	6403	5217	5217	5217
Firms	1008	949	949	949	1091	1054	1054	1054
No. of instruments	21	25	26	26	21	25	26	26
AR1 (p-value)	0.000	0.000	0.000	0.000	0.000	0.000	0.000217	0.000
AR2 (p-value)	0.731	0.360	0.367	0.363	0.098	0.174	0.175	0.175
Hansen-J (p-value)	0.765	0.579	0.572	0.582	0.009	0.0742	0.0741	0.0739

Standard errors in parentheses
* $p<0.10, **p<0.05, ***p<0.010$

The estimation results for large firms are reported in columns 5–8. The coefficient of lagged RD is significant at the 1 percent level, and are larger than those reported for MSMEs. As for MSMEs, lagged squared RD remains insignificant in all specifications. Lagged OpRevenue is insignificant for all specifications. The CashFlow coefficient decreases from a 1 percent significance level to 5 percent when the lagged and contemporaneous ΔCashHoldnings are included in the specification, with lower coefficients than in the sample with small firms. Lagged CashFlow is insignificant in all specifications. ΔCashHoldnings is negative and significant at the 1 percent, with negative coefficients that are slightly smaller in absolute value than for small firms. Lagged ΔCashHoldnings, BOR and ΔBOR2 are insignificant in all specifications.

5.3 Results for Listing Status

Table 5.3 presents the estimates for firms that are listed on the stock market and those that unlisted. The results for unlisted firms are displayed in columns 1–4. As has been the result of all specifications across the sample, lagged RD is significant at the 1 percent level in all specifications. Similarly to the results for MSMEs, the coefficients of lagged RD are relatively small and become smaller when controlling for lagged and contemporaneous ΔCashHoldnings.

Table 5.3: Results for Unlisted and Listed Firms

	Unlisted				Listed				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
RD_{t-1}	0.514***	0.477***	0.479***	0.476***	0.901***	1.024***	1.007***	1.007***	1.009***
	(0.139)	(0.162)	(0.161)	(0.161)	(0.142)	(0.162)	(0.145)	(0.145)	(0.144)
RD^2_{t-1}	0.201	0.375	0.365	0.385	-0.282	-0.346	-0.437	-0.449	-0.448
	(0.360)	(0.404)	(0.398)	(0.407)	(0.371)	(0.638)	(0.540)	(0.538)	(0.537)
$OpRevenue_{t-1}$	-0.00622**	-0.00525	-0.00497	-0.00517	-0.0125*	-0.0109	-0.0197	-0.0188	-0.0194
	(0.00305)	(0.00351)	(0.00351)	(0.00351)	(0.00705)	(0.0157)	(0.0146)	(0.0146)	(0.0147)
CashFlow	0.0572***	0.0694***	0.0700***	0.0683***	0.0339***	0.0343*	0.0439**	0.0436**	0.0439**
	(0.0111)	(0.0140)	(0.0140)	(0.0139)	(0.0125)	(0.0182)	(0.0171)	(0.0172)	(0.0170)
$CashFlow_{t-1}$	-0.0217***	-0.0178**	-0.0176*	-0.0182**	-0.00659	0.0112	0.00970	0.00935	0.00978
	(0.00786)	(0.00903)	(0.00902)	(0.00903)	(0.0125)	(0.0173)	(0.0198)	(0.0200)	(0.0197)
△CashHoldings		-0.0275***	-0.0276***	-0.0275***			-0.0390**	-0.0392**	-0.0392**
		(0.00645)	(0.00645)	(0.00645)			(0.0161)	(0.0161)	(0.0161)
$\triangle CashHoldings_{t-1}$		-0.00275	-0.00284	-0.00282			0.0121	0.0114	0.0117
		(0.00738)	(0.00740)	(0.00738)			(0.0166)	(0.0165)	(0.0166)
BOR_{t-1}			-0.00782**					-0.000613	
			(0.00346)					(0.00135)	
$\triangle BOR2_{t-1}$				-0.0126**					0.000879
				(0.00544)					(0.00137)
StkIssues						-0.0397**	-0.00613	-0.00524	-0.00525
						(0.0188)	(0.0264)	(0.0263)	(0.0267)
$StkIssues_{t-1}$						0.0291*	0.0267	0.0274	0.0274
						(0.0152)	(0.0223)	(0.0222)	(0.0225)
Observations	6919	5378	5378	5378	3943	2277	1963	1963	1963
Firms	1457	1362	1362	1362	577	476	464	464	464
No. of instruments	21	25	26	26	21	26	30	31	31
AR1 (p-value)	6.71e-08	0.0000117	0.000	0.000	0.000	0.00122	0.005	0.005	0.005
AR2 (p-value)	0.153	0.203	0.202	0.212	0.638	0.526	0.788	0.790	0.792
Hansen-J (p-value)	0.0590	0.0908	0.0904	0.113	0.615	0.694	0.719	0.708	0.715

Standard errors in parentheses
* $p<0.10$, $**p<0.05$, $***p<0.010$

Furthermore, the lag of RD^2 is insignificant in all specifications for unlisted firms. Lagged OpRevenue is negative and significant at a 5 percent level in Column 1. CashFlow is significant at the 1 percent level in all specifications, with a coefficient that increases when controlling for lagged and contemporaneous ΔCashHoldnings. The coefficient of lagged CashFlow decreases in absolute value and significance when controlling for lagged and contemporaneous ΔCashHoldnings. When including BOR the significance level drops even further, from the 5 percent level to the 10 percent level. However, when controlling for ΔBOR2, it is still significant at the 5 percent level. ΔCashHoldnings is significant at the 1 percent level in all specifications where it is included, with negative coefficients. Lagged ΔCashHoldnings is insignificant in all specifications. Most importantly, both BOR and ΔBOR2 are significant at the 5 percent level for unlisted firms, with negative coefficients which are relatively small in absolute value.

The results for listed firms are displayed in columns 5–9. The specifications differ from previous specifications by also including lagged and contemporaneous estimations of StkIssues. The lagged RD variable is significant at the 1 percent level for all specifications, and the coefficients are larger than for listed firms (1.02 compared to 0.51 when only controlling for lagged and contemporaneous CashFlow). The lag of RD^2 is insignificant in all specifications. OpRevenue is negative and significant at the 10 percent level when including only cash flow, and is negative and non-significant in all other specifications. CashFlow is positive and significant at the 1 percent level in Column 5, and the coefficient becomes slightly larger in size but less significant when adding contemporaneous and lagged StkIssues. Lagged CashFlow is insignificant in all specifications. Contemporaneous StkIssues has a negative coefficient which is significant at the 5 percent level in Column 6, while lagged StkIssues is positive and significant at the 10 percent level. Both lagged and contemporaneous StkIssues are insignificant in all other specifications. ΔCashHoldnings is negative and significant at the 5 percent level in all specifications, with a coefficient that is slightly larger in absolute value when including BOR and ΔBOR2. Lagged ΔBOR2 is positive and insignificant for all specifications. Neither BOR nor ΔBOR2 is significant in the sample with listed firms, and both coefficients are small in absolute values.

5.4 Analysis of the Results

The results reported in Section 5.1 are fairly consistent with previous literature on R&D financing. Across all specifications and categories, we find that CashFlow is significant and positive, indicating that R&D investment is subject to finance constraints. Similarly, we find that ΔCashHoldings is significant and negative. This result indicates that firms smooth their R&D expenditures, because of reductions in cash holdings allowing liquidity to be available for R&D expenditure. In addition, we find that the lag of RD is positive and significant, illustrating that R&D expenditures are persistent and once again indicating expenditure smoothing. Furthermore, we find three indications that MSMEs and unlisted firms are more financially constrained than large and listed firms. First, the coefficients of CashFlow for are higher for unlisted firms than listed firms, and for MSMEs they are almost twice the size of corresponding coefficients of large firms. Second, the coefficients of ΔCashHoldings are larger in absolute terms for MSMEs and unlisted firms than for large and listed firms. These results indicate financial constraints, implying that these firms need to fund a higher proportion of their R&D expenditures with internal funds compared to listed and large firms. Third, the coefficients of lagged RD are higher for large and listed firms than for MSMEs and unlisted firms. A plausible interpretation of this result is that R&D expenditures are less persistent for these firms because they are unable to smooth spending as well as large and listed firms – once again indicating that they are subject to more stringent financial constraints.

As for our main contribution – the addition of BOR and ΔBOR2 – it is evident that the results vary depending on which category is being considered. When interpreting the results of Table 5.1 containing all firms in the sample, neither the BOR nor the ΔBOR2 estimates is statistically significant. This result is to be expected because of the heterogeneity in the sample. As mentioned in section 2.3, we expect that the implementation of macroprudential policies will primarily affect the most financially constrained firms, which our theory and our results indicate are unlisted firms and MSMEs. The effects of macroprudential policies are not expected to be prevalent in large and listed firms with strong internal funds and/or better access to external sources of finance. Since these firms constitute a large part of the whole sample, the results of Table 5.1 are consistent with our theory.

Our theory is further supported by the results of Table 5.3, which present the results for listed and unlisted firms, and Table 5.2 presenting results for MSMEs and large firms. While the coefficients of BOR and ΔBOR2 are insignificant for large and listed firms, both are negative and significant at the 5 percent level for unlisted firms. Similarly, ΔBOR2 is negative and significant at the 10 percent level for MSMEs. However, the significant coefficients are small in absolute value relative to other variables. This result illustrates that R&D expenditure is primarily financed with internal funds, which is consistent with previous literature.

A somewhat unexpected result is that ΔBOR2 is significant for MSMEs but not BOR. The interpretation is that a tightening of macroprudential policies significantly reduces R&D expenditures but not an implementation, which could seem contradictory. Further evidence of this can be found in the results for unlisted firms, where the coefficient of ΔBOR2 is larger in absolute terms than that of BOR. A plausible explanation for this is that implementations of macroprudential policies are also coded as tightening measures in ΔBOR2, provided that they occurred during the sample period. Therefore, the coefficient of ΔBOR2 reflects the effect of both an implementation and a subsequent tightening. Another possibility is that the effect of going from 0 to 1 instrument in place is large, but that the marginal effect of adding one more is small. This situation would reduce the size of the coefficient for BOR.

5.4.1 Implications of the Results

Our results indicate that implementation and tightening of borrower-targeted macroprudential policies are associated with lower R&D expenditures for unlisted firms and to some degree for MSMEs. The main implication of this result is that such policies could have an adverse effect on economic growth, especially in countries with a large degree of MSMEs or with less developed stock markets. In other words, our results provide further evidence of a trade-off between stability and growth in the use of macroprudential policies, as suggested by Sánchez and Röhn (2016). Another implication is that unlisted firms and MSMEs are more dependent on bank loans to finance their activities than listed and large firms, and that they may use debt directly for their R&D investments.

Because the results suggest a trade-off, their inference could be used to formulate policies, depending on policy objectives. The aim of macroprudential policies is to increase financial stability, but knowing that this can come at the expense of economic growth suggests that cost-benefit analyses have relevance. Furthermore, it suggests that the choice of policy instrument is important. Thus far, there is only evidence that borrower-targeted macroprudential policies are associated with lower R&D expenditures and firm investments. Since evidence suggests that lender-targeted policies are effective in increasing stability but have not been shown to have the same adverse effects, use of these may be advantageous if the goal is to minimize the effects on firm investment. However, the results should be cautiously interpreted when discussing the effects of macroprudential policies. The aim of this study has not been to argue for fewer or less intense borrower-targeted policies but to provide evidence of the externalities they have on R&D expenditures. This study has only provided preliminary evidence that borrower-targeted macroprudential policies are associated with lower R&D expenditures. Though we have presented two possible explanations of how this may occur, we have not proven either of these causalities. Furthermore, the results are based on aggregated observations and can not explain the effects of individual policies in individual countries. Further research is needed to confirm and expand upon these findings.

5.5 Robustness Checks

5.5.1 Comparison to Brown et al. (2012)

When estimating the coefficients for large firms in our sample, the results differ from those of Brown et al. (2012), even though the baseline specifications and models are similar. This disparity can be explained by noting the difference in samples between the studie. Comparing our summary statistics in Table 3.1 to those in Brown et al., it is clear we have a different firm composition. The mean and median of employees in Brown et al.'s full sample is 10,607 and 1,570 respectively, which shows the firms in our sample are of considerably smaller size. Because Brown et al. only includes firms listed on the stock market, the mean of net proceeds from stock issues (0.108) is also higher than in our sample. This pattern can be observed throughout the rest of the comparison, with the variables in Brown et al. (2012) having slightly larger mean and median than the variables used in this study. Furthermore, Brown et al. defined large firms as those that were above the 70th percentile in terms of employees in their sample, not as those with more than 250 employees.

As a robustness check to make sure that the model is correctly specified, the model has been estimated using a similar size definition, instrument specification and listing status as Brown et al. Since our sample contains a lower median of employees, we defined large firms as those above the 90th percentile in terms of employees in our sample. Furthermore, only firms listed on the stock exchange are included. Comparing results to Brown et al.'s sample of large firms across Europe, we obtain similar results.[10] As in Brown et al. (2012), the lagged value of RD is large and positive, while the squared lag of RD is negative and large in absolute value. Furthermore, the coefficients of OpRev (sales in Brown et al. (2012)), StkIssues and sum of CashFlow and ΔCashHoldings variables are consistent with their results in both coefficients and level of significance. Therefore, our results imply that the baseline regression is correctly specified according to previous research.

5.5.2 Weighting the Sample

Because the model is estimated at an aggregate level and there is an uneven distribution of firms across our sample of countries, and some countries are over-represented in the sample. Since we expect macroprudential policies to have different effects in different countries, this over-representation could potentially skew the results. To control for this aspect, we estimate the model after inverse-weighting the sample. Each category (size and listing status) has been estimated with the full set of applicable financial variables, including BOR and ΔBOR2 respectively. Results including BOR are presented in Table 5.4 and results including ΔBOR2 are presented in Table 5.5.

[10] The estimation results can be found in Table 7.1 in the Appendix.

Table 5.4: Comparison of Weighted and Unweighted Results, BOR1

	SME		Large		Unlisted		Listed	
	Weighted	Unweighted	Weighted	Unweighted	Weighted	Unweighted	Weighted	Unweighted
RD_{t-1}	0.502***	0.560***	0.893***	0.898***	0.529***	0.479***	0.965***	1.007***
	(0.154)	(0.153)	(0.190)	(0.170)	(0.177)	(0.161)	(0.127)	(0.145)
RD^2_{t-1}	0.417	0.243	-0.591	-0.577	0.329	0.365	-0.405	-0.449
	(0.317)	(0.308)	(0.390)	(0.431)	(0.411)	(0.398)	(0.414)	(0.538)
$OpRevenue_{t-1}$	-0.00174	-0.00593*	-0.00140	-0.00301	-0.00346	-0.00497	-0.0184	-0.0188
	(0.00452)	(0.00353)	(0.00673)	(0.00503)	(0.00448)	(0.00351)	(0.0150)	(0.0146)
BOR_{t-1}	-0.0114*	-0.00749*	0.000439	0.000428	-0.00654	-0.00782**	-0.000717	-0.000613
	(0.00670)	(0.00447)	(0.00147)	(0.00110)	(0.00560)	(0.00346)	(0.00156)	(0.00135)
CashFlow	0.0645***	0.0612***	0.0444**	0.0330**	0.0636***	0.0700***	0.0376	0.0436**
	(0.0131)	(0.0124)	(0.0190)	(0.0129)	(0.0159)	(0.0140)	(0.0232)	(0.0172)
$CashFlow_{t-1}$	-0.0146	-0.0173*	0.00453	-0.00393	-0.0200*	-0.0176*	0.00915	0.00935
	(0.0106)	(0.0102)	(0.0128)	(0.00947)	(0.0108)	(0.00902)	(0.0213)	(0.0200)
△CashHoldings	-0.0370***	-0.0313***	-0.0312***	-0.0280***	-0.0292***	-0.0276***	-0.0426*	-0.0392**
	(0.00845)	(0.00812)	(0.00899)	(0.00767)	(0.00726)	(0.00645)	(0.0228)	(0.0161)
$△CashHoldings_{t-1}$	0.00293	0.00676	-0.0130	-0.00999	-0.00113	-0.00284	0.0162	0.0114
	(0.00998)	(0.00899)	(0.00850)	(0.00719)	(0.00770)	(0.00740)	(0.0187)	(0.0165)
StkIssues							-0.00962	-0.00524
							(0.0227)	(0.0263)
$StkIssues_{t-1}$							0.0355**	0.0274
							(0.0159)	(0.0222)
Observations	3827	3827	5217	5217	5378	5378	1963	1963
Firms	949	949	1054	1054	1362	1362	464	464
No. of instruments	26	26	26	26	26	26	31	31
AR1 (p-value)	0.000	0.000	0.001	0.000	0.000	0.000	0.006	0.005
AR2 (p-value)	0.363	0.367	0.118	0.175	0.356	0.202	0.816	0.790
Hansen-J (p-value)	0.692	0.572	0.204	0.0741	0.0375	0.0904	0.717	0.708

Standard errors in parentheses
* $p<0.10$, ** $p<0.05$, *** $p<0.010$

As illustrated in Table 5.4, results are similar when comparing weighted and unweighted samples. Considering MSMEs, OpRevenue ceases to be significant when weighting the sample. However, the coefficient is still small in absolute value. Furthermore, the CashFlow in the listed firm sample is no longer significant when the sample is weighted. The coefficient of ΔCashHoldings becomes larger in absolute value but less significant in the weighted sample for listed firms, while StkIssues becomes significant at the 5 percent level. The lag of BOR is not significant in the weighted sample for unlisted firms, compared to being significant at the 5 percent level in the unweighted sample. A possible explanation for this result, that is consistent with our theory, is that countries that have gained more weight in the sample are more market-based. As discussed in Section 2.3, we suspect firms in these countries to be less dependent on bank loans therefore be less affected by implementation of borrower–targeted policies. Another possible explanation is that countries that have more weight in the sample contribute with unlisted firms that are large. Since large firms are expected to be less financially constrained, they should also be less affected by implementation of borrower–targeted policies.

Table 5.5: Comparison of Weighted and Unweighted Results, BOR2

	SME		Large		Unlisted		Listed	
	Weighted	Unweighted	Weighted	Unweighted	Weighted	Unweighted	Weighted	Unweighted
RD_{t-1}	0.500***	0.560***	0.892***	0.896***	0.518***	0.476***	0.968***	1.009***
	(0.154)	(0.152)	(0.190)	(0.168)	(0.179)	(0.161)	(0.125)	(0.144)
RD^2_{t-1}	0.426	0.246	-0.590	-0.573	0.353	0.385	-0.404	-0.448
	(0.319)	(0.310)	(0.390)	(0.430)	(0.418)	(0.407)	(0.411)	(0.537)
$OpRevenue_{t-1}$	-0.00190	-0.00597*	-0.00132	-0.00293	-0.00352	-0.00517	-0.0193	-0.0194
	(0.00452)	(0.00355)	(0.00691)	(0.00502)	(0.00449)	(0.00351)	(0.0156)	(0.0147)
$\triangle BOR2_{t-1}$	-0.00140	-0.00189	0.000394	0.0000815	-0.0114**	-0.0126**	0.000456	0.000879
	(0.00610)	(0.00551)	(0.00111)	(0.000892)	(0.00558)	(0.00544)	(0.00122)	(0.00137)
CashFlow	0.0648***	0.0611***	0.0447**	0.0331**	0.0628***	0.0683***	0.0371	0.0439**
	(0.0132)	(0.0124)	(0.0189)	(0.0129)	(0.0159)	(0.0139)	(0.0231)	(0.0170)
$CashFlow_{t-1}$	-0.0148	-0.0177*	0.00449	-0.00402	-0.0206*	-0.0182**	0.00981	0.00978
	(0.0105)	(0.0101)	(0.0129)	(0.00950)	(0.0109)	(0.00903)	(0.0212)	(0.0197)
$\triangle$CashHoldings	-0.0369***	-0.0312***	-0.0311***	-0.0280***	-0.0292***	-0.0275***	-0.0421*	-0.0392**
	(0.00842)	(0.00814)	(0.00897)	(0.00766)	(0.00727)	(0.00645)	(0.0228)	(0.0161)
$\triangle CashHoldings_{t-1}$	0.00308	0.00708	-0.0132	-0.0100	-0.00149	-0.00282	0.0164	0.0117
	(0.00999)	(0.00897)	(0.00846)	(0.00721)	(0.00774)	(0.00738)	(0.0188)	(0.0166)
StkIssues							-0.0101	-0.00525
							(0.0232)	(0.0267)
$StkIssues_{t-1}$							0.0354**	0.0274
							(0.0161)	(0.0225)
Observations	3827	3827	5217	5217	5378	5378	1963	1963
Firms	949	949	1054	1054	1362	1362	464	464
No. of instruments	26	26	26	26	26	26	31	31
AR1 (p-value)	0.000	0.000	0.001	0.000	0.000	0.000	0.006	0.005
AR2 (p-value)	0.357	0.363	0.118	0.175	0.368	0.212	0.817	0.792
Hansen-J (p-value)	0.694	0.582	0.201	0.0739	0.0432	0.113	0.719	0.715

Standard errors in parentheses
* p<0.10, $**p<0.05$, $***p<0.010$

Table 5.5 displays a comparison on weighted and unweighted results when controlling for ΔBOR2. As is the case in Table 5.4, weighted and unweighted results are very similar. When considering this specification, the lagged difference of ΔBOR2 continues to be significant at the 5 percent level with a coefficient marginally lower in absolute value. That ΔBOR2 continues to be significant after weighting but BOR does not further supports our previous results that indicate that a tightening of borrower-targeted instruments have more effect than an implementation.

6 Conclusion

This study has analyzed the relationship between borrower–targeted macroprudential policies and firm spending on R&D. Using a system GMM approach on a sample of European firms, we have provided preliminary evidence that implementation and tightening of such policies are associated with lower R&D spending for unlisted firms and to some degree for MSMEs. However, the effect of borrower-targeted policies on R&D is small compared to the effects of other financial variables such as cash holdings and cash flow. This result is consistent with previous research, which suggests that R&D is primarily financed using internal funds.

We have proposed that unlisted firms and MSMEs are affected because they are more financially constrained than large and listed firms, and that these constraints become more stringent after implementation and tightening of borrower–targeted policies. Furthermore, we have suggested that the causality between borrower–targeted policies and reduced R&D expenditures can either be direct or indirect. If direct, firms use bank loans to some degree in order to fund their R&D expenditures. If indirect, firms use internal funds to finance R&D and use bank loans to fund other activities which become subject to finance constraints after implementation and tightening of policies. Firms will then need to substitute their use of bank funds for those activities with internal funds. Since these are limited, firms will need to prioritize their use of them and possibly choose to reduce R&D expenditure.

To the best of our knowledge, this is the first study to investigate the relationship between R&D expenditure and macroprudential policies. Since our results indicate a relationship between the two, further research on the topic is of interest. For example, we have been unable to investigate the difference between bank– and market–based economies. Further research can therefore focus on specific countries or investigate how the effects differ based on the size and quality of financial institutions. Furthermore, we have not provided conclusive evidence of either of the proposed causalities mentioned above. Another suggestion for further research is therefore to examine the R&D financing decision compared to other types of investment and include controls for external debt. Such a study could empirically investigate if the effect of borrower-targeted policies on R&D investment is indeed an indirect effect of it being deproioritized compared to less risky investments.

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7 Appendix

Table 7.1: Specification of Brown et al.

	(1)	(2)	(3)
RD_{t-1}	0.998***	1.139***	1.438***
	(0.204)	(0.158)	(0.311)
RD^2_{t-1}	-0.978**	-1.367***	-1.721***
	(0.443)	(0.292)	(0.597)
$OpRevenue_{t-1}$	0.00206	0.00242	-0.0186
	(0.00559)	(0.0121)	(0.0153)
CashFlow	0.0165	0.0502	0.0797
	(0.0158)	(0.0539)	(0.0509)
$CashFlow_{t-1}$	0.0127	0.00434	0.0468
	(0.0127)	(0.0239)	(0.0311)
StkIssues		0.0412	0.0728
		(0.0715)	(0.0608)
$StkIssues_{t-1}$		-0.0126	-0.0195
		(0.0266)	(0.0640)
△CashHoldings			-0.0426
			(0.0335)
$\triangle CashHoldings_{t-1}$			-0.0395*
			(0.0227)
Observations	1560	984	850
Firms	226	196	192
No. of instruments	21	26	30
AR1 (p-value)	0.0136	0.0563	0.0250
AR2 (p-value)	0.993	0.980	0.599
Hansen-J (p-value)	0.539	0.0787	0.0792

Standard errors in parentheses
* p<0.10, $**p<0.05$, $***p<0.010$

Table 7.2: Countries Included in the Full Sample

Country	Firms
AT	22
BE	20
DE	233
DK	32
ES	8
FI	42
FR	75
GB	1296
GR	18
IE	23
IT	8
LU	10
NL	24
SE	266
Total	2078