# Debt maturity structure and corporate innovation

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## 1. INTRODUCTION

"Innovation can be defined as the application of new ideas to the products, processes, or other aspects of the activities of a firm that lead to increased "value." This "value" is defined in a broad way to include higher value added for the firm and also benefits to consumers or other firms" (Greenhalgh and Rogers 2010). This is why innovation is considered as one of the main engines to keep a firm continuing to transform and thus, to cope with the strong competition in the marketplace. "Innovation is no longer the buzzword of tech firms, but companies in all industries must be on top of their creative game to compete" a BCG's partner expert on innovation strategy said. Given the role of corporate innovation in the firm's life, however, the question that often remains open (to not only practitioners but also researchers), "How these innovative activities are financed to be successful given their attributions: risky – there is a high probability of failure, but also prospects for extraordinary returns; unpredictable – many future contingencies are impossible to foresee; long-term and multi-stage investment – the project has an invention, a development and a completion stage, and can be terminated between those; idiosyncratic – not easily comparable to other projects; labour intensive – all stages require substantial human effort (Holmstrom 1989)"? Innovation decisions are a part of investment decisions but they do not follow the regular rules to be selected such as the net present value of a project or the internal interest rate and/or the time back period because in practice, firms do not care about the idiosyncratic risk but they do care about financial constraints. With a limited amount of capital, firms have to allocate these financial resources to different proposed investment projects and in most cases the demand vastly exceeds the offers.

Although theoretically the link between financing and innovation was pointed out by Schumpeter (1942) and then following by numerous studies such as Hall (1992), Aghion & Tirole (1994), Himmelberg and Petersen (1994), Hall (2002), Gompers (2002). However, as stated before, innovative firms (firms which run innovative projects) have specific characteristics that may explain some difficulties in raising

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funds. Clearly, innovative investments are characterized by an extreme uncertainty, a high proportion of specialized equipment and intangible assets (knowledge, R&D expenditures) and by sunk costs. Hirshleifer et al. (2011) argue that information about new technologies is hard for investors to process as it requires knowledge about how the economic fundamentals are changing. It also requires the analysis of the innovation process, from new ideas to final products on the market, as the expected profit of such activities is highly uncertain. An alternative hypothesis makes a different empirical prediction. As Holmstrom (1989) points out, unlike routine tasks such as mass production and marketing, innovative activities involve the exploration of untested and unknown approaches that have a high probability of failure and the innovation process is risky, long-term and multi-stage, and idiosyncratic. Therefore, firms investing more heavily in innovative projects may have to make partial disclosure and are subject to a greater degree of information asymmetry (Bhattacharya and Ritter 1983), then are more likely to be undervalued by outside investors, and have a hard time raising required capital to fund innovative projects (Myers, Majluf, and Myers 1984).

In this thesis, we study how capital structure, especially, debt structure decisions can have an impact on corporate innovation. Many studies on financing firm's innovation highlight the role of internal resources or equity as the main channels to finance and thus give the incentives to the firm's innovation. Firms which invest in innovation, tend to have limited debt capacity, especially when they are young and small. Since innovative projects are certainly risky, banks/financial institutions may be especially cautious in the lending process and require more collateral. Even through Schumpeter's "ephor of capitalism" states that the bank plays an important role in helping to get innovations financed, "Debt typically must be secured by collateral when the borrowing firms are risky" (Berger & Udell, 1990). Firms which are involved in innovative activities often find it hard to demonstrate to banks the collateral related to the requested loan and the final innovative project value is also frequently not available as well. Tangible assets, like fixed capital, are the usual forms of collateral accepted by creditors, mainly banks (Hall, 1992), but the majority of assets owned by firms which engage in innovation are intangibles like intellectual property.

For the reasons stated, there are only a few studies which mention the debt in innovation financing. Taking an example of UK industrial firms over the period 1990–2002, Aghion et al. (2004) shows that firms performing R&D as an innovation input tend to use more debt than firms without R&D activities but the use of debt declines with the size of the innovative effort and the most R&D-intensive firms tend to issue equity, thus suggesting a possible non-linear relationship between innovation and debt finance. Recently, Gu, Mao, and Tian (2013), Amore, Schneider, and Žaldokas (2013), Cornaggia and Wolfe (2015) examine the relation between bank development/deregulation and firms innovation outputs. However, none of them examine how debt maturity structure could have an impact on the corporate innovation success. I fill the gap in the literature by studying the impact of debt maturity structure on corporate innovation.

Going back to the beginning, studies on the interaction between financing and investment corporate policies have the cornerstone from the capital structure irrelevance principle of Modigliani and Miller (1958). Once, this relationship has been developed and demonstrated in numerous theoretical and empirical researches. Jensen and Meckling (1976), Myers (1977), Jensen (1986) and Stulz (1990) examine two agency problems resulting from debt financing namely "underinvestment" and "overinvestment". On one hand, Jensen & Meckling (1976) point out the asset substitution problem. After debt is in place, equity holders will undertake overly risky projects because the payoff to them resembles the payoff from a call option on firm value. Jensen (1986), Stulz (1990) reveal the "overinvestment" problem where conflict of interest is between management and shareholders; the argument is that managers have a propensity to expand the scale of the firm even if that means undertaking poor projects and reducing shareholder welfare. Management's ability to carry out such a policy is constrained by the availability of free cash flow, and this constraint can be further tightened via debt financing. The issuance of debt requires the firm to pay cash as interest and principal, forcing managers to service such commitments with funds that may have otherwise been allocated to poor investment projects. Thus, leverage is one mechanism for overcoming the overinvestment problem suggesting a negative relationship between debt and investment for firms with weak growth opportunities.

On the other hand, in the classic papers (Myer, 1977), and later (Mello, Parsons, 1992), (Parrino & Weisbach, 1999), (Mauer & Ott, 2000), (Hennessy, 2004), (Titman & Tsyplakov, 2007) the idea is given the "underinvestment or debt-overhang" problem where equity holders will pass up those projects which have positive net present values, but mostly benefit the debt holders. Hence, highly levered firms are less likely to exploit valuable growth opportunities as compared to firms with low levels of leverage. A related underinvestment theory also examines a liquidity effect in that firms with large debt commitments invest less irrespective of the nature of their growth opportunities.

The implications of these side by side comparison studies on agency cost are demonstrated on numerous empirical research such as (McConnell & Servaesb, 1995), (Lang, Poulsen, and Stulz 1995), (Aivazian et al 2005b), (Aivazian, Ge, and Qiu 2005a), (Singh & Faircloth, 2005), (Ahn and Denis 2006) which examine the impact of corporate financing policies on investment decisions and all of them confirmed the strong negative impact of leverage on the corporate investment.

In this study, consistent with the "underinvestment" point of view, we suppose that the use of short-term debt enhances a firm's innovation output. In contrast, the more long-term debt a firm decides to indebt, the less successful in innovative activities in term of quantity and quality a firm can get. By considering the success of innovative activities (number of patents and citations of patent), we assume that the investment on innovation is fully recognized as a firm's high-growth option. In the presence of a high growth option, a firm can act like an agent and a principal who owns capital and a potential moral hazard problem can be created. A principal who supplies risky debt to high-growth investment but uncertain requires high costs to the firm. In this case, a firm may forgo these innovative projects which promise high return but most of the return will then benefit to principal. To mitigate this problem, one possible solution is negotiating capital supplying contracts in the way that principal and agent can both benefit from that above high-growth investment. Thus, the use of short-term debt contract will permit both firm and creditor to reconsider and make an arrangement on their interest on the investment opportunities ex-post. Supporting this view are Barne, Haugen, and Senbet (1980) who find that short term maturities preserve financing flexibility as well as its future ability to invest, thus firms whose investment opportunity sets contain more growth options should employ a higher proportion of short-term debt. Aivazian et al. (2005a) also show that lowering leverage and shortening debt maturity have a positive effect of growth opportunities in investment with the additional assumption that underinvestment incentives can be controlled completely through the ex ante restructuring of leverage and debt maturity.

Using a large panel of US firms covered by the Nation Bureau of Economic Research (NBER) Patent and Citation Database, fundamentals and debt maturity structures from COMPUSTAT data period 1976 – 2006, our main results are that debt which matures less than one year (short-term debt) has a positive and significant impact on the quantity and quality of innovation output, measured by the number of patents and number of patent citations, respectively. It means that we found long-term debt (Proportion of debts which are due more than one year and less than five years) has a negative impact on the corporate innovation outputs. Various robustness checks with different terms of debts, all result from the baseline model hold.

In terms of methodology, our research project is conducted in a panel data setting which controls for the heterogeneity among the individual firms. First, we use the baseline with the fixed effects (industry level) regression on a set of independent variables which represent the firm's characteristics and controlled by the leverage. Dependent variables proxies in turn are corporate innovation outputs namely the number of patents and the correspondent citations.

To address the concerns of the unobservable firm specific effects and joint endogeneity of the explanatory variables in innovation regressions, first, we use the Generalized Method of Moments (GMM) approach developed by M. Arellano & Bond (1991), Arellano and Bover (1995), Roodman (2009). The system GMM estimator explicitly treats independent variables (the debt maturity structure proxies and fundamental variables) as endogenous, and uses these lagged independent variables (internal instruments) and fixed effects to account for these endogenous relations. Results from running the system GMM model are consistent with our hypothesis and baseline models.

We also used the PVAR (vector autoregression in the panel data) to account for reverse causality between the whole independent variables with corporate innovation, which was developed by Love and Zicchino (2006). PVAR give the users the advantage of dealing with the problem when all variables are considered endogenous and interdependent. PVAR also gives us a visual interaction of changes of debt maturity and corporate innovation outcomes and vice versa.

We also performed a variety of tests to check our results but they still hold.

Since most previous studies on financing corporate innovation focus on the internal financing or equity channel/venture capital resource, only a few mentioned debt financing but related to investment decisions and growth option. Our study gives a contribution to the literature of capital structure and corporate innovation, especially on the topic of financing innovation through a debt channel. To the best of our knowledge, I am the one of the first who has jointly studies the impact of debt maturity structure on the success of a firm's innovative activities and also by using PVAR, I show the two-way relationship between capital structure, debt maturity structure and corporate innovation.

The outline of this study will be as follows, section 2 provides additional discussion of the related literature and develop hypothesis of the thesis. Based on the study of previous literature, we provide all details on the data and methodology applied on empirical analysis in section 3. In the next section we present and discuss empirical results. Finally, conclusions are reached in section 5.

## 2. LITERATURE REVIEW

Our study on debt financing corporate innovation is compiled based on two groups of literature. The first is related to characteristics of innovative investment and how firms allocate their internal/external financial resources to finance innovative projects. The second strand of literature which studies the interaction between the financing, especially on debt maturity decisions and investment decisions and then a special case of investment: "Innovative investment" which very often has high uncertainty on the return expected, idiosyncratic and requires at least a medium to a long term. That strand of the literature which considers the agency cost of outstanding debt confirms the negative impact of leverage on corporate investment decisions[2]. One area of research related to this point of view but with different results is presented in the papers of Diamond (1991 and 1993) and Sharpe (1991) is the theory of risk liquidity. They point out that the use of excessive short-term debt can create risk of liquidity, thus, increasing the bankruptcy cost and constrains a firm's debt capacity. The relationship between the investment decision and debt maturity is the trade-off between a decrease in agency costs and an increase in bankruptcy costs. Therefore, decisions on debt maturity also depend on the capacity of the firm to deal with the liquidity risk. In Diamond model the time structure of returns from the investment

[2] (Myers, 1977), (Jensen, Meckling, 1976), (Jensen, 1986), (Aivazian et al. 2005b), (Aivazian et al. 2005a), (Ahn and Denis 2006)

project is kept fixed. Hart and More (1994) discuss how the debt maturity structure varies with the timing of project returns.  In detail, a model in which the entrepreneur cannot be replaced without high cost, they show that the faster the returns arrive, the shorter will the optimal repayment structure of debt will be. This is to conclude that the maturity of assets and liabilities should be matched. A support of the conventional view about the theory of matching of maturity of liabilities and assets is also provided by Myers (1977). Since assets in place allow the firm to support more debt, one can expect of matching as scheduling debt repayments to correspond with the decline in the value of existing assets.

We focus on the impact of the debt maturity structure on corporate innovation to give a contribution to this uncompleted picture. We find evidences supporting Myer's hypothesis and show short-term debts enhance the success of corporate innovative activities (number of patents and number of patent citations). By doing this, our study complements the studies of Aivazian et al. (2005a), which shows that the use of long-term debt in controlling leverage reduces a firm's investment level.

Furthermore, our results from additional analysis also give partial evidence to the liquidity risk hypothesis, in which Johnson (2003), Barclay and Smith (1995) and Barclay, Marx, and Smith (2003) confirm that the use of short-term debt can mitigate underinvestment, but excessive levels may create a liquidity risk. These authors use the trade-off theory to explain short-term debt policy which enables firms to increase the leverage. If a high growth firm uses short-term debt to mitigate the underinvestment effects, then it leads to an increase in leverage and a positive relationship between the leverage and growth opportunities. We found that on one hand, short-term debt enhances productive corporate innovation but on the other hand, leverage level harms it, which means firms then may face the trade-off between the cost of underinvestment problem ex-post and the risk of liquidity created by overusing short-term debt.

### 2.1 Corporate innovation literature

"Innovation is not a new phenomen" (Fagerberg 2004). The research on "innovation" covers a vast area from the very beginning of the whole supply chain of innovation to its end, and the role of innovation in social life and the global economy. As illustrated in Figure 1, the number of social – science publications focusing on innovation recently has increased much faster than in the past.

*<Insert Figure 1 here>*

Most of the primis literature on corporate innovation studies the innovation under the lens of the input elements which is typically R&D expenses. Schumpeter (1942) has argued the importance of financial resources such as internal finance in financing R&D investment. R&D investment is then considered as an important input for any corporate innovation activities. Recently, the studies on corporate innovation consider step by step not only the input of the innovation chain but also the successful corporate innovation activities.

In this study, we focus on how the structure of corporate financing policies has an impact on the success of innovative activities. We start by considering the figures created by innovation characteristics and make innovative investment to be different from other ordinary investment.

On one hand, Holmstrom (1989) and Bergemann and Hege (2005) argue that innovation projects involve a high probability of failure (the return is uncertain), and the innovation process is unforeseen and idiosyncratic with many future contingencies that are very difficult to understand how it will proceed. In fact, Steven and Burley (1997) estimate that it takes about 3,000 raw ideas to eventually achieve a single major commercially successful innovation. A key issue here is to distinguish innovation, the bringing to market of a truly novel item, from imitation, the adoption of a new technique or design that is already in the market. A product or process can be new to the firm, new to the domestic market, or new to the world market. “Innovation involves the exploration of new untested approaches that are likely to fail” (Manso 2011). Figure 2 shows how complicated stages of the innovation process are with the participation of many different parties.

*<Insert Figure 2 here>*

Uncertainty is inherent in the innovation process, as decisions to bear risk by doing R&D cannot be separated as an element of choice from decisions to wait for returns (investment), as noted by Arrow (1962). This is because insurance against the failure to discover something important and profitable by undertaking R&D is not on offer. This concentration of risk on particular firms who decide to engage in R&D may lead to underinvestment, especially in smaller firms, which cannot use product diversity to spread their R&D risk within the firm (Greenhalgh and Rogers 2010). Uncertainty related to the output of innovation tends to be high at the very first stage of the innovation process then decreases step by step with each passing stage. The differences of uncertainty in innovative projects from the others are that it can be “extreme and not a simple matter of a well-specified distribution with a mean and variance” (Hall 2002). Scherer (1998) also finds that the distribution of profits from innovation sometimes has a Paretian character where the variance does not exist. When this is the case, standard risk – management methods will not work as normal.

What is more, not everyone can understand innovative projects unless they are innovators themselves. In most innovative cases, there is not (or there are very little) tangible assets linked to the subject. Hall (2002) argues that in practice fifty per cent or more of R&D spending is the salaries of highly educated scientists and engineers. In fact, the efforts of these ultimate’s figures created an intangible asset, the firm’s knowledge base. However, this firm’s knowledge is related to its human capital and if these employees decide to leave, this intangible asset will disappear. One more idea is that innovative activities often require long time to process. As we can see from the innovation process (Figure 2), each stage of innovation needs a certain period of time. In many cases, some stages may repeat many times.

On the other hand, innovative investment is also associated with asymmetric information between the investors and the firm itself (Hall 2002), (Bergemann and Hege 2005), (Bhattacharya and Ritter 1983), (Hall and Rosenberg 2010). The asymmetric information problem refers to the fact that an inventor frequently has better information about the likelihood of success and the nature of the contemplated innovation project than potential investors (Hall 2002), (Hall and Rosenberg 2010). In fact, one of the typical characteristics of innovation is that only inventors can understand how innovative projects work. Moreover, disclosure information costs to the firm create “asymmetric information” between the investors and inventors. Firms are motivated to communicate their privately known attribute to a subset of uninformed agents, but they can do so only through channels or signals which convey directly useful information to other competing agents (Bhattacharya and Ritter 1983). Thus, the implication of asymmetric information coupled with the costliness of mitigating the problem is that firms and inventors would suffer a higher cost of external than internal capital for R&D due to the lemon’s premium. Furthermore, firms also have to consider the tradeoff between the costs of disclosure of information to their potential rivals (advantages of private information) and external financing or benefits, from the cost of raising external financing. Bergemann and Hege (2005) argue that when the informational relationship between investors and inventors are not completed, frequently in the case of arm's-length investors (typically angel investors) who are less informed.

To sum up, innovative investment is atypical of an ordinary firm's investment, thus each related financial decision needs to be considered under many different lenses to achieve the highest efficiency.

**2.2 Financing corporate innovation literature**

Firstly, looking at the studies on the relationship between financing decisions and investment decisions, the milestone was the Modigliani - Miller propositions where leverage and investment were unrelated. By this time, corporate finance literature had relaxed the perfect capital market assumption and examined different market conditions, to conclude that leverage and investment had a strong relationship. Jensen and Meckling (1976), Myers (1977), Jensen (1986) and Stulz (1990) examine two agency problems resulting from debt financing namely "underinvestment" and "overinvestment". We will review them with more detail hereafter.

More recently, McConnell & Servaesb (1995), Lang, Poulsen, et al. (1995), Aivazian et al (2005b), Ahn and Denis (2006) examine the impact of corporate financing policies on investment decisions and all of them confirmed the strong negative impact of leverage on corporate investment. Using a large non-financial US dataset, Mcconnell and Servaesb (1995) show that corporate value is negatively correlated with leverage for firms with strong growth opportunities and positively correlated with leverage for firms with weak growth opportunities. Lang, Ofekb, and Stulz (1995) find a strong negative relationship between leverage and subsequent investment, but only for the firms with low Tobin's q ratios. Better firms do not have valuable growth opportunities. Aivazian et al. (2005b) examine a sample of Canadian publicly trading companies and they find that leverage negatively affects a firm's investment and this negative effect is significantly stronger for the firms with low growth opportunities. Ahn and Denis (2006) divide their sample, which includes diversified firms, into two subsamples, core business and non-core business. They find that leverage has a negative impact on a firm's investment and this negative effect is significantly greater for high Tobin's q segments than low Tobin's q segments. The same conclusion of negative impact of leverage on investment is significantly greater is found in non-core business than that in core business.

Then, considering the relationship between corporate financing policies and innovative investment as a special case of ordinary firm investment, previous studies show that there exists a “pecking order” of financing corporate innovation (Casson et al. 2008), (Brown et al. 2009), (Bartoloni 2011). Brown et al. (2009), Casson et al. (2008) conclude that internal sources are preferred. Kamien and Schwartz (1979) and Spence (1979) also point out that the rate of innovation depends on the availability of internal resources. Kamien and Schwartz (1979) give two reasons for the difficulty of receiving external financing for innovative projects: “i) external financing may be difficult to obtain without substantial related tangible collateral to be claimed by the lender if the project fails; ii) the firm might be reluctant to reveal detailed information about the project that would make it attractive to outside lenders, fearing its disclosure to potential rivals.” Hall (2002) shows that it may be difficult or costly to finance R&D using capital from external sources to the firm entrepreneur. That explains why some innovative projects fail because the costs of external capital are too high. The author finds evidences that small and startups firms in R&D face a higher cost of capital than their larger competitors firms in other industries. He also concludes that internal funds are preferred for large firms. Venture capital is an easy solution for financing innovation due to its limitations such as limited in some industries, with a certain size that is often too large for startups in some fields.

Likewise, Brown et al. (2009) underline the importance of equity finance when the firm does not have sufficient internal funds. He gives “a financing hierarchy for R&D at least for young firms which consists almost entirely of internal and external equity finance”. Internal sources are served first then when cash flow is exhausted and debt is not an option, firms must turn to new share issues. He shows that internal equity finance is high volatile and “the 1990s internal finance boom was likely the results of a number of favorable but temporary, shocks to nominal interest rates, oil prices, and exchange rates combined with quasi-fixed labor costs”. Dass et al. (2013) have argued that “equity financing may also be better matched to the needs of firms developing innovative products and technologies that have a longer gestation period and may require greater managerial discretion”.

Furthermore, Kortum and Lerner (1998), Kortum and Lerner (2000), Gompers (2002), Bergemann and Hege (2005), Lerner, Sorensen, and Omberg (2011), and Tian and Wang (2014) show the role of venture capital in innovative activities. Kortum and

Lerner (2000) find that venture capital investments positively affect innovation. By exploring the history, structure and performance of corporate venture programs in the US, Gompers (2002) explains why corporate venture capital is more successful than independent venture capital. Lerner et al. (2011) have argued that private equity (LBO) does not impede corporate long-term investment (proxied by patenting activity and the economic importance of innovation).

By using UK dataset, Casson et al. (2008) confirm "control rights" theories of financing, in which debt is preferred to equity since it involves less loss of control rights. The study shows that the probability of issuing new equity rises monotonically with the level of expenditure on R&D, while the use of debt finance follows an inverted U curve, rising and then falling as R&D rises. The mode of financing is associated with the characteristic types of innovation where debt financing is related to incremental innovation and equity funding with R&D intensive innovation. Results from the study of Singh and Faircloth (2005) show that there is a strong negative relationship between the degree of financial leverage and the level of R&D expenditure that firms undertake. Furthermore, they find that higher leverage that leads to lower R&D expense rather than R&D causing variations in future leverage.

Bhattacharya and Ritter (1983) present a model in which firms engaged in R&D activity possess private information that is valuable in its research and if disclosed, only in the research of its competitors. They argue that pursuing R&D activities requires firms to raise external financing and that was the only way that these firms accepted to disclose some of information from their innovative projects. Therefore, informed firms had to consider the tradeoff between reducing the value of its informational advantage and raising financing at better terms which reflects its innovation prospects.

### 2.3 Debt maturity structure and a firm's investment

Aivazian et al. (2005a) show that the use of long-term debt in controlling leverage reduces a firm's investment level (for a firm with a high growth option) and this relationship is not significant for firms with a low growth option. Consistent with this view, Dang (2011) in his paper considers the triangle relationship between leverage, debt maturity structure and firm investment. By examining a panel of U.K. firms, he finds that high-growth firms control underinvestment incentives by reducing leverage but not by lowering debt maturity. He also confirms the liquidity risk hypothesis by finding evidence that there is a positive relationship between leverage and debt maturity. Finally, he concludes (consistent with the overinvestment hypothesis), that leverage hurts firm investment. In contrast, debt maturity does not have any direct impact on investment. However, having long-term debt maturity appears to discourage firms from exploiting valuable growth opportunities and creates underinvestment ex post. Johnson (2003) examines the two relative problems: why if short-term debt mitigates the negative effects of underinvestment then leverage still has a negative impact on growth opportunities. He used the risk of suboptimal liquidation theory presented in the study of Diamond (1991, 1993) and Sharpe (1991) to conclude that firms face a tradeoff between the cost of underinvestment problems against the cost of an increased liquidity risk when they decide a short-term debt maturity policy.

We focus on the specifics of the financing source that is debt and study which maturity structure of debts give more incentives to corporate innovation. We suppose that long-term debt have a negative impact on the output of corporate innovation considering innovative projects are high growth option for firms. Lowering the debt maturity means firms will renegotiate with the creditors more times and after each time of renegotiation debt contract, shareholders may gain full benefits from a new contract then mitigate the negative effects of underinvestment (in the innovative projects investment) on the outputs of corporate innovation. Consistent with the view of Johnson (2003), we will show that to force the outputs of corporate innovation (the success of innovative investment) thus high growth opportunities of firms, they can shorten the debt maturity, this may enable the presence of liquidity risks. Therefore, firms should reduce the leverage level to keep themselves as safe as possible from the risk of liquidity.

### 2.4 Underinvestment vs overinvestment

Jensen and Meckling (1976), Myers (1977), Stiglitz and Weiss (1981), Myers and Majluf (1984), Jensen (1986) and Stulz (1990) examine two agency problems resulting from debt financing namely “underinvestment” and “overinvestment”. They state that in the imperfect conditions of capital market, asymmetric information and agency costs could lead to underinvestment or overinvestment, and therefore positive projects may not be selected or negative NPV projects may be not rejected. The following figure shows how these issues are connected.

While underinvestment and overinvestment problems have several similar predictions for the potential interactions among leverage, growth opportunities and investment, they have different implications for firms with different growth prospects. The underinvestment problem is more likely to be present in high-growth firms, while the overinvestment problem is more likely to arise in low-growth firms (Dang 2011).

Jensen (1986) examines the agency cost from the conflict between managers and shareholders, especially when firms have a substantial cash flow and poor growth options. Firm's managers have incentives to use the excess cash flows to invest in even lower return on expected projects. In these cases, debts are used to mitigate the effects of overinvestment. By doing this, managers will use the excess cash flow to pay out the interest and the principal and thus reduce the investment in new projects with expected return rate lower than the discounted rate. They conclude that leverage negatively affects a firm's investment.

The interaction between the leverage and corporate investment is also discovered by the seminal paper of Myers (1977) which shows that a levered firm might bypass investments in positive NPV projects just because by making that investment, the shareholders increase both equity value and the value of the debt-holders claims and if the last one is larger than the projects NPV then the projects overall value might be negative under the equity-holders view. This phenomenon is called debt overhang or underinvestment which refers to the fact that levered firms invest less than similar unlevered firms. Myers predicts that firms with greater growth opportunities face greater underinvestment problems so they have an incentive to use shorter-term debt. To mitigate the underinvestment effects, firms can reduce their leverage or shorten the maturity of outstanding debts. The use of short-term debt which expires before an investment project is implemented enables shareholders to gain full benefits from the new project through renegotiation of the debt contract so that gains from new projects do not accrue to debt holders. The paper concludes that if the other things are equal, growth opportunities should be financed less by debt than assets-in-place.

Furthermore, the conflict between shareholders and bondholders gives rise to underinvestment problems by adverse selection (Stiglitz and Weiss 1981). Since bondholders do not have enough information to qualify among many firm's investment projects, they would require a higher premium for the capital they own. Thus, firms may bypass some investment projects even if they have a positive NPV, rather than issue risky debt. Myers et al. (1984) highlights the role of pre-contract asymmetric information between current and prospective shareholders. The conflict between current and prospective shareholders may also lead to an underinvestment problem by adverse selection. They show that firm may not undertake positive NPV projects due to pre-contract asymmetric information about the investment projects and the assets in place. Prospective shareholders who owe informational asymmetries are unaware of the firm value and raise the price at which they would offer funds. At that price, the existing shareholders may lose more if these investment projects are undertaken than they would if the investment projects were abandoned.

Consistent with the above prediction, Barclay and Smith (1995), Guedes and Opler (1996), and Barclay et al. (2003) study firm's debt maturity choices and find the same conclusion on the relationship between maturity and growth opportunities. They find that firms with more growth opportunities have less long-term debt and thus there is a positive relationship between the debt maturity and investment opportunities of firms.

To sum up, the underinvestment hypothesis is one of the key issues to in understanding the interaction between financing policies and growth opportunities.

## 3. RESEARCH SAMPLE, DATA AND METHODOLOGY

### 3.1 Sample

To measure the quantity and quality of innovation output, we use data from the NBER Patent and Citation Database, which provides detailed information on all U.S. patents granted by the U.S. Patent and Trademark Office between 1976 and 2006 (Hall, Jaffe, and Trajtenberg, 2001) . The database covers over 3.2 million patent grants and 23.6 million patent citations from 1976 to 2006 and contains information about patent assignee names and their Compustat-matched identifiers, the number of citations received by each patent, the technology class of the patent, and similar details. There is, on average, a two-year lag between the date when inventors file for patents (the application date) and the date when patents are granted (grant date). On this database, at first I had 312.914 observations in the period from 1967 to 2006. Since the latest year in the database is 2006, patents applied for in 2004 and 2005 may not appear in the database. As suggested by Hall, Jaffe, and Trajtenberg (2001), we restrict our sample period to end in 2003.

Data on debt maturity structures and firm characteristics was obtained from Compustat. To define the average debt maturity, we use the balance sheet data of Compustat, which includes the amount of current debt or short-term debt (debt repayable within one year), total amount of long-term debt (which is the amount of long-term debt payable in two to five years[3]), and very-long-term debt (that is the debt due in more than five years).

Then we merged the two databases: the one for patents and the one for debt maturity structures and firms characteristics. We considered ranged only from 1976 until 2003. Following Hirshleifer, Low, and Teoh (2012) and Chang et al. (2015), we excluded firms in any four-digit SIC industries that had no patents between 1976 and 2003 and firms in financial and utility industries (SIC code: 6000-6999 and 4900-4999, respectively) because they are subject to different regulatory and accounting considerations. Firms with missing values for debt structures are also excluded. These restrictions resulted in a large sample that consisted of 20,858 firms (192,899 firm-years observations) for which the average debt maturity can be measured using the Compustat data. When we ran PVAR or GMM, we imposed more restrictions on the data because these models required the use of lags, only firms that have five years or more observations are retained. Furthermore, any at observation that has missing data for variables of interest is removed. Data on stock prices and returns are retrieved from the Center for Research on Security Prices (CRSP) files. Dollar values are converted into 2000 constant dollars using the GDP deflator.

### 3.2 Measuring corporate innovation

Measures of corporate innovation have typically involved one of the two major aspects of the innovative process: (1) a measure of the inputs into the innovation process, such as R&D expenditures[4]; (2) an intermediate output, such as the number of

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[3] As pointed out by (Barclay and Clifford W 1995), one advantage of the *Compustat* balance-sheet data is its broad view of corporate debt. Long-term debt includes bonds, mortgages, capitalized lease obligations, and publishing companies' royalty contract payable, and similar long-term fixed claims. Short-term debt includes short-term notes, the current portion of long-term debt, sinking funds, installment on loans, and bank acceptances and overdrafts. Thus our debt maturity measures cover many important parts of the credit market such as domestic and Euro-commercial paper, asset-backed receivables financing, private placements, and bank debt.

[4] (Hall, 1992), (Hall et al., 1998), (Bougheas 2004), (Aghion et al., 2004), (Zimmermann and Muller 2009), (Brown and Petersen 2011), (P. Aghion, et al. 2012)

inventions which have been patented[5]. This measure then often goes along with the number of citations of a patent which indicates the patents quality. R&D expenditures suffer from measuring only the budgeted resources allocated towards trying to produce innovative activity. Furthermore, more firms innovate than they do R&D or they have available R&D data. Larger firms have a higher propensity of carrying out R&D and innovating than smaller firms. What is more, not all R&D expenditures are well spent, and some critics of major corporations (Jensen 1993) suggest that many corporate research activities are wasteful and yield a low return, changes in R&D expenditure.

Our first measure of innovation output is the number of patents applied for by a firm in a given year (*Patents*). Our study is also related to recent papers that use patents as the dependent variable or outcome (e.g.,(Chang et al. 2015), (Tian and Wang 2014), (Sevilir and Tian 2012), (Fang, Tian, and Tice 2013), (Cornaggia and Wolfe 2015)). These papers implicitly assume that patents represent a valuable outcome. Of course there are shortcomings in using patent applications as a measure of innovative output. All patents cannot be thought to have equal value. Some represent significant innovation, while others represent peripheral innovation. Some patents are held for only a short period. It is also known that the propensity of a patent differs from industry to industry, since the effectiveness of the patent system protecting intellectual property rights is not equal in all fields. Despite these shortcomings, the number of patent applications is still an useful index for measuring the innovative knowledge production of a firm (Wakasugi and Koyata 1997). We also adjusted the patent count for truncation by dividing the number of patents by the mean value of patents across all firms in the same year, where the mean value of patents is calculated only based on firms with patents.

Patent counts, however, imperfectly capture innovation success because patents vary drastically in their technological and economic significance (Hirshleifer et al. 2012). According to Griliches (1979) and Pakes and Griliches (1980) “patents are a flawed measure (of innovative output) particularly since not all new innovations are patented and since patents differ greatly in their economic impact”. We therefore

[5] (Hall 2005), (Hall 2009), (Aghion et al., 2004), (Bergemann and Hege 2005), (Benfratello et al. 2008), (Brown et al, 2009), (Gompers et al. 2003), (Bartoloni 2011), (Amore et al. 2013), (Aghion et al. 2013), (Cornaggia and Wolfe 2015)

follow (Hall, Jaffe, and Trajtenberg, 2001, 2005) and use forward citations[6] of a patent to measure its quality importance[7]. The raw citation counts suffer from truncation bias due to the finite length of the sample. As patents receive citations from other patents over a long period of time, patents in the later years of the sample have less time to accumulate citations. We use two methods to deal with this truncation bias:

Firstly, we adjust each patents raw citation counts by multiplying it with the weighting index *hjtwt* of Hall, Jaffe, and Trajtenberg (2005), provided in the NBER database. The weighting index *hjtwt* is derived from a quasi-structural model, where the shape of the citation-lag distribution is econometrically estimated. QCitation is then the sum of the adjusted citations across all patents applied for during each firm-year.

Secondly, we adjust the raw citation counts using the fixed-effect approach, which involves scaling the raw citation counts by the average citation counts of all patents applied for in the same year and in the same technology class. The fixed-effect approach accounts for the differing propensity of patents in different years and in different technology classes to cite other patents[8]. We use Tcitation to denote the sum of the adjusted citations during each firm-year under this alternative adjustment approach.

### 3.3 Measuring the debt maturity structures

We denote the amount of total debt as $D_t$ (the sum of current debt and long-term debt), the amount of debt maturing in $i^{th}$ year as $D^i$, and the amount of debt maturating in more than *i* years as $D^{>i}$. Thus, $D^{>i}/D$, as a measure of debt maturity structure, represents the ratio of debt due in more than *i* years to total debt. Long-term debt is typically defined as debt due after either 1 year (Scherr and Hulburt, 2001), (Fan, Titman, and Twite 2012), (Dang 2011), 3 years (Barclay and Smith 1995), (Barclay et al. 2003), (Johnson 2003), and (Datta, Iskandar-datta, and Raman 2005), *(*Aivazian et

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[6] The number of citations is calculated over the entire life of the patent. We do not exclude self-citations in the baseline regression since Hall, Jaffe & Trajtenberg (2005) find that self-citations are more valuable than external citations. They also suggest that self-citations, which require generating further related patents, are indicative of the firm's competitive advantage in the relevant technology and thus should be more important than other citations. Results from our empirical research do not change if I exclude self-citations.

[7] We include self-citations since Hall et al. (2005) find that self-citations are more valuable than external citations. They argue that self-citations, which come from subsequent patents, reflect strong competitive advantages, less need for technology acquisitions, and lower risk of rapid entry.

[8] See (Atanassov et al. 2005) and (Hirshleifer et al. 2012) for detailed discussions on the advantages and disadvantages of this approach

al., 2005a)) or 5 years (Ozkan 2001). Stohs and Mauer (1996) suggest adopting the weighted average of debt maturity as a measurement for debt maturity dependent variables. Because of the availability of detailed debt maturity data in the Compustat database, numerous US researchers employ a weighted average of debt maturity measurement in their research such as based on the work of Stohs and Mauer (1996). We use the proportion of debt maturing in more than 1 year and less than 5 years ( $D^{25} / D$ named D25 for short) as our main measure of debt maturity. Accordingly, we define debt maturing in more than 1 year and less than 5 years as "Long-term", debt maturing more than 5 years as "Very-long-term" ($D^{>5}/D$ named D5 for short) and debt maturing in 1 year or less as "Short-term" ($D^{<1}/D$ named STD for short) for the purposes of the subsequent empirical analysis[9]. This division of maturity structure helps me see the separated effect of short-term debt, long-term debt and the use of very long-term debt on the quantity of patents and the importance of number of patents.

### 3.4 Control variables

To isolate the effect of debt and debt maturity structures on innovation output, we control for an array of firm characteristics that have been documented as important determinants of innovation by previous studies. We thus use firm size measured as the log of total assets. There are controversial opinions on this issue. From one side, Kamien and Schwartz (1975) find that firm size does not appear especially conductive to either innovational effort or output. Agreeing with this view, Scherer (1984) and Holmstrom (1989) examine numerous tests on the relationship between firm size and productive R&D and the conclude that "large corporations contributed fewer significant innovations, contest-winning technical advances and invention patents per million dollars of R&D than smaller enterprises". Furthermore, Bound et al. (1984) also find that small firms, that are R&D active, tend to patent more for R&D dollar than larger firms. On the other side, Kamien and Schwartz (1975) characterize the Schupeterian debate as firm size is positively related to innovation in terms of both the amount of effort and the success. Acs and Audretsch (1987) show that the relationship between firm size and innovation is dependent on the characteristics of firms and the

[9] Admittedly, it is arbitrary to draw a line between short-term and long-term debt using the cutoff of 1 year. As discussed in a later section, the robustness checks indicate that our results hold with alternative measures of debt maturity structure (debt maturing more than one year on the total debt, debt maturing more than 3 years on the total debt).

industry which firms operate in. Symeonidis (1996) finds that innovative outputs measured against R&D expenditure does not increase with firm size, and it may in fact even decrease. This finding might be interpreted as a scale disadvantage in the production of innovation. However, he also finds that “positive linkages between concentration/size and innovative activity can occur when certain conditions are met, including high sunk costs per individual project, economies of scale and scope in the production of innovation rents”.

We believe that firm size, for different reasons, such as: economies of scale and concentration of human and capital resource, positively correlate with innovation outputs.

Firm age is measured as the number of years that firms enter in the CRSP database. Innovative activities often require making huge investments in R&D projects and taking substantial risks. It also involves learning from mistakes and failures that are an unavoidable part of the innovation process. Therefore, the knowledge that is gained even from failures can be applied to improve other products. However, only firms with sufficient accumulated profits may be able to survive when one innovative project fails. Empirical evidence shows that old firms are, on average, larger and possess a larger accumulated stock of profits. Thus, firm age may positively affect the success of innovative investment. What is more, young firms often have to face up to difficulties related to the lack of market recognition and economies of scale and the lack of alliances with partners. While over time, firms are able to strengthen their available resources, managerial knowledge and the ability to handle uncertainty (Herriott, Levinthal, and March 1984), (Levitt and March 1988). As they have a higher reputation and market position which facilitate relationships and contacts. There is evidence on the positive effect of firm age on new product development (Hansen 1999), (Sivadas and Dwyer 2000) and innovative outcomes (Tripsas and Gavetti 2000).

R&D on total assets is assumed as a proxy for the R&D expenses. Chang et al., (2013) also argues that firms which engage in more R&D activities innovate more. R&D expenses serve as an important input to innovation, apart from human capital, the efforts and creativity of managers, employees (Atanassov, Nanda, and Seru 2005). Thus, there should be a positive relationship between the amount of resources allocated to R&D and R&D output. This means the higher the expense of R&D, the higher the output (Chiesa and Masella 1996). Following Chemmanur and Tian (2013), Hirshleifer et al. (2012), Chang et al. (2015) missing R&D expenses are treated as zero.

Labor productivity is a variable defined by the log of the net sales scaled by the number of employees (Ln(Sales/#employees)). It is included to proxy for quality as higher labor productivity may lead to higher innovation productivity. Hall et al. (2001) argue that large, mature and capital intensive firms are associated with more patents and citations. Griliches (1979, 1995, 2000) has explored the role of R&D in productivity growth and found evidence of a positive and significant impact, with some variability in terms of magnitude.

Following John (1993) and McVanel and Perevalow (2008), who report a positive relationship between R&D expenditures and corporate liquid holdings, we use the assets liquidity/total assets to control the liquidity of assets. Return on assets (ROA) is included to capture profitability. As discussed above, the more profitability a firm has the more innovative outcomes a firm can achieve.

We also use assets growth ($(at_t - at_{t-1})/at_{t-1}$) as a proxy for growth opportunities. The market-to-book ratio (M/B) (Chang et al., 2013) shows that firms with more resources, higher market to book ratio or greater stock volatility are also more innovative.

We include the cash-to-assets ratio (Cash/Assets) to account for cash holding to control for the role of internal resources in financing innovation (Himmelberg and Petersen 1994). The literature on R&D also provides evidence that the innovative sector is cash-intensive. Mikkelson and Partch (2003) study a sample of U.S. industrial firms with persistently high cash holdings and conclude that these firms are considerably more R&D intensive than the average firm. More recently, Brown and Petersen (2009) point out that publicly traded young R&D firms in U.S. manufacturing rely extensively on cash holdings to carry out their R&D spending and that, contrary to firms not reporting R&D expenses, R&D firms have considerably increased their cash holdings over the period 1982-2006.

The book value of leverage ratio (Leverage) is added to account for the effects of capital structure on innovation. As discussed before, innovative investment is often uncertain with respect to the outcome of an R&D project, an asymmetric information problem between borrower and lender emerges. As a result, banks and other possible investors are reluctant to finance such investments (see (Hall 2002)). A high level of leverage increases the cost of risky “debt overhang” thus firms may forgo valuable investment such as innovative projects, and may reduce the innovative outcomes ex-post. On the other hand, a low level of leverage helps mitigate the underinvestment incentives and allows more growth opportunities taken on investment. Thus, a lower level of debt in financing structure is predicted to positively affect innovative outputs. Dividend payer is assumed as a dummy variable, used to control if a firm is a cash dividend payer or not in the year. Dividend payout by cash reduces a firms free cash flow, thus, could affect a firm's investment on innovation (Aivazian, Booth, and Cleary 2003).

Herfindahl index is used to control product market competition (Chemmanur and Tian 2013), (Atanassov et al. 2005), (Chang et al. 2015). It is measured by the Herfindahl index (Industry Herfindahl index based on all Compustat firms where industries are defined by 3-digit SIC) on sales. Aghion et al. (2005) document an inverted U-shape relationship between product market competition and innovation. Squared Herfindahl index is a control variable to capture possible non-linear relation between product market competition and innovation (Aghion et al. 2005). We also include the squared Herfindahl index in the baseline regressions.

To mitigate the impact of outliers or misrecorded data, all financial variables from Compustat are winsorized at the 1% level at both tails of their distributions. All debt structures, debt maturity structures and control variables are measured at *t-1* in the regressions. The detailed variable definitions are tabulated in the Appendix.

## 3.5 Models

### 3.5.1 Baseline

We examine the effect of debt maturity structures and debt structures on a firm's innovation outputs using the baseline model as follows:

$$Innov_{i,t} = \alpha_0 + \alpha_1 Debt\_Mat_{i,t-1} + \alpha_2 Lev_{i,t-1} + \alpha_3 Controls_{i,t-1} + Year_i + Industry_{i,t} + \varepsilon_{i,t} \quad (1)$$

where $Innov_{i,t}$ refers to our innovation measures (*Patents, QCites, and TCites*) of firm *i* in year *t*. We consider the first measure of innovation is Patents (Log of one plus number of patents)[10]. The next measures of innovation are *QCites and TCites* which are the log of one plus the number of citations.

[10] Our results do not change qualitatively if I use the "time-technology class fixed effect" method to adjust for the difference in patenting practices across different technological fields (Atanassov, 2012), (Hiershleifer, Low, and Teoh, 2012)). This method scales the number of

$Debt\_Mat_{i, t-1}$ represents our debt maturity structure. As explained above, $D^{25}_{i, t-1}/D_{i, t-1}$ it is the main explanatory variable of interest, long-term debt. In the robustness, We use an alternative measure of long-term debt such as $D^{>1}/D$ (debt maturing more than one year on the total debt), $D^{>3}/D$ (named D31 for short Debt maturing more than 3 years on the total debt).

$Lev_{i, t-1}$ is the total book value of debt divided by the total book value of assets.

$Controls_{i, t-1}$ is the set of control variables. Specifically, I control for R&D effort by including R&D expenses over the total assets (R&D/Assets), firm size (Log of total assets), firm age (the number of years in which the firm has been entered in the CRSP database); liquidity (the total of liquid assets on the total assets), MB, profitability (ROA), cash ratio, sale growth, dividend payer (dummy variable which assumes value 1 if a firm is a dividend cash payer and 0 if a firm is not), labor productivity (log of the net sales scaled by the number of employees (Ln(Sales/#employees)), Herfindahl index (Industry Herfindahl index based on all Compustat firms where industries are defined by 3-digit SIC) on sales.

We also include two-digit SIC industry[11] and yearly fixed effects in the model.

### 3.5.2 GMM model

The use of dynamic panel data estimation (GMM system) has many advantages in estimating the impact of a debt maturity structure on corporate innovation. The most significant aspect of using GMM is dealing with a potential endogeneity problem by allowing me to choose more efficient instruments. The endogeneity problem is crucial in this study because it is possible that observed relationship between corporate innovation and debt maturity structure, firm specific characteristics reflect the effects of corporate innovation on the latter and vice versa. GMM is used to control for unobservable firm specific fixed effects and firm invariant time specific effects. Firm specific effects are controlled by estimating the dynamic corporate innovation model in first differences then in levels. The system GMM technique explicitly treats the independent variables as endogenous, and uses lagged independent variables (internal instruments) and fixed effects to account for these endogenous relations. Specifically,

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patents by the average number of patents issued in a certain year by all firms for a given class technology. The detailed results are in the robustness checks section.

[11] Both our innovation measures and debt maturity structures are highly persistent variables (untabulated shows Wooldridge test for the presence of autocorrelation in panel data), therefore, I include industry fixed effects rather than firm fixed effects in the regressions.

the instruments for the regression in levels are the lagged differences of the corresponding variables, and the instruments for the regression in differences are the lagged levels, under the assumption that the differences of these variables are not correlated with the unobservable firm specific effects. We also control for time specific effects by including year dummies in the estimated models. The instrument variable approach involves transforming the dynamic equations by first-differencing them to eliminate the individual effects and their potential correlation with the lagged values. Applying this technique to the equation of Innovation the following transformed equation:

$$\Delta Innov_{i,t} = \Delta\alpha_1 Innov_{i,t-1} + \Delta\alpha_2 Debt\_Mat_{i,t-1} + \Delta\alpha_3 Lev_{i,t-1} + \Delta\alpha_4 Controls_{i,t-1} + \Delta\varepsilon_{i,t} \quad (2)$$

The model provides AR1, AR2 test result which gives evidence for first order and second order serial correlation, respectively. The Sargan test (Stata reports the Hansen J statistic instead of the Sargan) also indicates that the instrument used in the GMM estimation are valid which shows that the instruments used are not correlated with the error term.

### 3.5.3 PVAR Model

The causal relationship between debts and innovation can be bidirectional. While our results report that short-term debt has a positive impact on a firm innovation, as the underinvestment hypothesis suggested, firm's innovative activities have an important role on financing policies, especially on indebt structures decisions. The coefficients estimated in an OLS regression of debt maturity on leverage and other variables will suffer from simultaneous-equation bias.

This problem also can be found in other works in which researchers regress one corporate policy choice on another using OLS such as Geczy, Bernadette, and Schrand (1997) who regress the use of foreign currency derivatives on leverage and managerial compensation variables; Berger, Ofek, and Yermack (1997) regress leverage on executive compensation variables; Tufano (1996) regresses hedging activity on leverage; Houston and Christopher (1996) regress the fraction bank debt on leverage; and Fama and French (2002) regress leverage on target payout ratios. All of these regressions suffer, to some degree, from the problems associated with multiple endogenous variables (Barclay et al. 2003).

To deal with the issue of the relationships between debt ratio and profitability, innovation and profitability and debt ratio and profitability, Bartoloni (2011) applies standard bi-directional Granger-causality tests (Granger 1969), (Sims 1972). The author uses a Vector Autoregressive Representation similar to that originally proposed by Holtz-Eakin, Newey, and Rosen (1988) and shows that a firm's leverage does not cause innovation output, as proxied by a measure of a firms successful innovation, while it is instead caused by successful innovation and a firms operating profitability.

We use a panel vector autoregressive (PVAR) approach which estimates the following two-equation reduced-form model:

$$Innov_{i,t} = \alpha_0 + \alpha_1 Innov_{i,t-1} + \alpha_2 Debt\_Mat_{i,t-1} + \alpha_3 Lev_{i,t-1} + \alpha_4 Controls_{i,t-1} + f_i + x_t + \varepsilon_{i,t} \quad (3)$$

$$Debt\_Mat_{i,t} = \beta_0 + \beta_1 Innov_{i,t-1} + \beta_2 Debt\_Mat_{i,t-1} + \beta_3 Lev_{i,t-1} + \beta_4 Controls_{i,t-1} + g_i + y_t + \omega_{i,t} \quad (4)$$

$f_i, g_i$ are firm-specifics unobserved heterogeneity;

$x_t, y_t$ are year fixed effects

$\varepsilon_{i,t}, \omega_{i,t}$ are identically and independently distributed errors

The PVAR approach has been used in several recent studies (e.g., (Grinsten and Michaely 2005), (Love and Zicchino 2006), (Goto, Watanabe, and Xu 2009)) to disentangle the causal effects and investigate intertemporal interactions between endogenous variables. Using PVAR lets us isolate the response of corporate innovation outcomes on the debt maturity structure change while allowing for unobserved firm heterogeneity. By keeping the fundamentals constant, using the orthogonalized shocks, in this case, the impulse response of innovations outputs to debt maturity structure shock while holding other shocks constant. However, since the actual variance – covariance matrix of the errors is unlikely to be diagonal, thus to isolate the shocks of other variables it is necessary to decompose the residuals in a way that they become orthogonal. "In applying the VAR procedure to panel data, we need to impose the restriction that the underlying structure is the same for each cross-sectional unit. Since this constraint is likely to be violated in practice, one way to overcome the restriction on parameters is to allow for "individual heterogeneity" in the levels of the variables by introducing fixed effects, denoted by $f_i$ in the model. Since the fixed effects are correlated with the regressors due to lags of the dependent variables, the mean-differencing procedure commonly used to eliminate fixed effects would create biased coefficient” (Love and Zicchino 2006). Following this indication, we take the forward mean-differencing approach (the Helmert procedure), which removes the fixed effects by transforming all variables in the model to deviations from forward means, i.e., the mean values of all future observations for each firm in a given year.

This transformation preserves homoscedasticity and the orthogonality between transformed variables and lagged regressors (Arellano and Bover 1995), enabling us to use the lagged values of regressors as instruments to estimate the coefficients with the GMM approach[12]. Year fixed effects are removed by subtracting the mean value of each variable computed for each year.

Using the PVAR approach has several advantages over individual firm VARs. Firstly, we gain degrees of freedom by analyzing a panel of firms. Further, we can better model the spillovers from one firm to another since the panel approach captures firm-level heterogeneity. Panel VARs seem particularly suited to addressing issues that are currently at the center stage of discussions in academics as they are able to (1) capture both static and dynamic interdependencies, (2) treat the links across units in an unrestricted fashion, (3) easily incorporate time variation in the coefficients and in the variance of the shocks, and (4) account for cross sectional dynamic heterogeneities.

## 4. EMPIRICAL RESULTS AND DISCUSSIONS

### 4.1 Summary statistics

Table 1 summarizes all variables used in the empirical analysis.

*[Insert Table 1 about here]*

Columns (1), (2), (4) of Table 1 respectively report means, standard deviations, medians of the variables used for the whole sample. Similarly, columns (3), (5) report their first and the third quartile.

Mean (median) leverage is 0.25 (0.22), and varies widely across firms where standard deviation is 0.22. Market-to-book has a mean (median) of 2.36 (1.35), which implies that the average (median) firm has valuable investment opportunities, and thus potentially faces the type of underinvestment problems described by Myers (1977).

For the corporate innovation measures, summary statistics reveal that approximately an average firm in our sample has roughly 6 patents and receives 51 raw

[12] In this case the model is “just identified”, the number of regressors equals the number of instruments, therefore system GMM is numerically equivalent to equation-by-equation 2SLS

citations for its patents every year. Untabulated summary statistics report the mean value of number of patents (raw) and number of citations (raw) by year, 1976 – 2003. Looking at the whole period from 1976 until 2003, we notice that the mean value of raw number of patents keeps constant in the 1970's and slowly reduces in the 1980's. From the 1990's, innovative outcomes show a strong rise and reach a peak in 2001 (9.88). Meanwhile, the quality of corporate innovation (number of patents' citations) seems slightly different. In the 1990's, the mean number of patent citations show the highest value in comparison to other decades. The highest one is found in 1995 with 75 citations. Untabulated statistics reveal also that the same pattern is also found for both *QCites* and *TCites*. The average citation of patents adjusted based on the weighting scheme of Hall, Jaffe, and Trajtenberg (2001 and 2005) (QCites) and on the year and technology class fixed effect method (*TCites*) are around 7 and 86, respectively. All of these values vary in a huge range: standard deviation of number of patents (raw) is 60.41, standard deviation of citations (raw) is 541.36 and that one of *TCites* is highest which is 1001.04. As all median value of these variables are 0, compared to their mean value, the distributions of patent (raw) and citation counts (raw), *QCites*, *TCites* are highly skewed. Thus, we use the log value of one plus various innovation measures in the regression analysis to mitigate the effect of skewness.

The first interesting aspect of debt maturity structure is that the mean value of short-term debt is approximately the mean value of debts which are due in more than four years (0.35) while the mean value of debts which are due in more than two years is much higher (0.51). On average, only 28% of debt matures in more than five years. Overall, approximately half of long-term debt matures before the fifth year. This results are not far from the results found by Custódio, Ferreira, and Laureano (2013) where debt maturity structure is extracted from all U.S. firms in the Compustat Industrial Annual database over the period 1976-2008. The authors find that firms are using more short-term debt regardless of their characteristics and shortening of debt maturity has increased the exposure of firms to credit and liquidity shocks. Consistent with this view, in our study we will show that the use of short-term debt is connected to the innovative characteristics of firms and the overuse of short-term debt would create tension of liquidity to firms. The next interesting aspect of debt maturity structure is that long term debt ratio (debt which matures more than one year and no more than 5 years) fluctuated during the whole interested period and varied in a broad range (with the standard deviation starting at 0.21 in 1976 and reaching 0.34 in 2003. Meanwhile, the mean value of very long term debt (proportion of debt matures more than five years) reduced from 0.42 in 1976 to 0.21 in 2003 and its range of variation was also kept limited (standard deviation varies from 0.27 to 0.30).

*[Insert Table 2 about here]*

Table 2 presents the Pearson correlation matrix between innovation proxies and debt maturity structure proxies, a firm's characteristic variables. All pair-wise correlations are significantly different from zero at the 1% level. As expected, our three measures of innovations, Patents, QCites, and TCites, correlate highly with each other (correlation coefficients are about 0.95 and significant at the 1% level). Consistent with our hypothesis, long-term debt correlates negatively with all three measures of innovations but its magnitude is relatively small (correlation coefficients of approximately -0.08 and they are significant at the 1% level). The same results are also found for the correlation between leverage and innovation proxies (correlation coefficients of approximately -0.11 and significant at 1% level). The correlation between innovation measures and R&D intensity is positive (correlation coefficients of approximately 0.13 and significant at the 1% level). The correlations between the control variables are reasonably low in most cases thus multicollinearity is not an issue in our tests.

## 4.2 Results

In this section, we examine the effect of debt maturity structure on the quantity and quality of a firm's innovative activity using the multivariate regression analysis in which the dependent variable is Logarithm of one plus number of patents (Npatents), Logarithm of one plus number of QCites (QCites) and Logarithm of one plus number of TCites.

### 4.2.1 Baseline results

Firstly, we regress only leverage and firm's characteristics on corporate innovation measures. The following table report the results of our baseline regressions in equation (1) omitted the debt maturity structure measures.

$$Innov_{i,t} = \alpha_0 + \alpha_1 Lev_{i,t-1} + \alpha_2 Controls_{i,t-1} + Year_i + Industry_{i,t} + \varepsilon_{i,t} \quad (4)$$

Firstly, we present the effects of Leverage on innovation outputs using OLS with fixed effects on the time and industry.

*[Insert Table 3 about here]*

As consistent with what we previously expected before, we find that Leverage gives a negative impact to corporate innovation outcomes. All coefficients are statistically significant at the 1% level. However their absolute values are smaller than those in the first regression. In fact, eeconomically, increasing leverage from its 25th percentile (0.06) to the 75th percentile (0.39) decreases the number of patents, number of patents modified, QCites, and TCites by 13.11%, 13.46%, 25.44% and 12.02% from their respective means. These decreases from their mean value are much smaller than those before. Control variables show expected signs on the innovation (not for cases of Liquidity, Herfind index and Herfind index square whose coefficients are not statistically significant any more but most of them still give the expected signs). Adjusted R square in all four regressions are much higher than those in the first regressions (Adjusted R squares are 0.388, 0.325, 0.354, 0.351 for the fixed effects on time and industry in the regression with dependent variable are Lnpat, Cnpat, QCites,

Next, after confirming the impact of leverage on the corporate innovation, we analyze the role of debt maturity structure on innovation outputs. Using the equation (1) as the base, we do the regression on the debt maturity measure (Long-term debt) controlled by the Leverage, Very-long-term debt, and a firm's characteristics variables.

*[Insert Table 4 about here]*

Table 4 presents the results from running OLS for Long-term Debt (D25) controlled by Leverage, Very-long-term Debt (D5) with fixed effects on time and industry. This time, we use innovation measures such as Lnpat, QCites and TCites. In an untabulated test with Cnpat, we are able to replicate the results if our dependent variable is Cnpat instead of Lnpat, QCites and TCites. Untabulated statistics show that the mean Variance Inflation Factor (VIF) is 2.43, lower than 10, suggesting that multicollinearity is still not a big issue in our case. In this table, we find that leverage, long-term debt and very-long-term debt are negatively and significantly related to all three measures of innovations Lnpat, QCites, TCites with t-statistics of 8.0, 9.5, 8.1. Economically, in Table 4 , increasing long-term debt from the 25th percentile (0.42) to the 75th percentile (0.93) decreases the number of patents, QCites, and TCites by 12.28%, 16.08% and 10.73% from their respective means[13]. The results are consistent

[13] To calculate the effect of Long-term debt on the change in the number of patents from its mean value, I first multiply the change of Long-term debt from the 1st quartile (0.42) to the 3rd quartile (0.93) by the coefficient on leverage (-0.206), and then by the mean number of patents (5.93) plus one. It is so because $dLn(1+y)/dx = (dy/dx)/(1+y)$, $dy = [d(\ln(1+y)/dx] (1+y) dx$

with the underinvestment theory as I explained in section 2. The more long-term debt a firm chooses, instead of short-term debt in the debt maturity policy, the less innovation outputs in terms of both quantity and quality they can achieve. Very-long-term debt also registered a negative impact on innovation outcomes in both regressions. This finding is consistent with the view of Johnson (2003) where the author confirms that the more a firm uses short-term debt, thus using less long-term debt, the more innovation outcomes a firm can produce. One implication from this policy is that shortening debt may enable the presence of liquidity risks thus, once again, firms should reduce leverage to save themselves from the risk of liquidity.

Our results on control variables are broadly in line with what we expected before. As we found in the previous model, Firm size, Firm age, R&D expenditures and M&B are significant at the 1% level and carry the expected signs. Unlike Hall, Ziedonis (2011), Labour productivity is negatively related to innovation outcomes. In Table 11, they are not significantly at the 1% level anymore but still significant at the 5% level. Profitability, Dividend has the expected sign but not significant. Meanwhile, Liquidity, Sale growth, Herfind index and Herfind index square do not carry either any sign as expected nor are statistically significant.

**4.2.2 GMM results**

To address the concern of unobservable firm specific effects and joint endogeneity of the independent variables in corporate innovation resgression, I use the system Generalized Method of Moments (GMM) approach developed by Arellano and Bover (1995). Our instruments for the transformed equations include GMM lags 4 years (and longer) of the endogenous variables on the right-hand side, and lags 3 of the differences for the level equations.

Table 5 presents the results using the system GMM estimation for Long term Debt as debt maturity. Our system-GMM model passes the Hansen test of overidentification with p-values of 0.207, 0.104 and 0.095 in three equations correspondent to three innovation measures as dependent variables which confirms the

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The change of patent (dy) from its mean value (5.93) is then equal to -0.7280=(0.93-0.42) x (-0.206) x (5.93+1). Due to the mean value of number of patents (raw) is 5.93 patents, a decrease 0.8919 patents from its mean value represents a 12.28% decrease from its value.
In the same way, we find that the changes of QCites, Tcites from their mean values are -1.068, -9.232, respectively. As Qcitation mean value is 6.64, thus a decrease of QCites represents a 16.08% decrease from QCites mean value. The same for TCites is a decrease of 10.73% from its mean value.

overall validity of the instruments (even the last is slightly weak). The autoregressive (AR) test indicate no second-order serial correlation in the differences error term as p-values for the Arellano-Bond (2) test are all larger than 0.1[14].

*[Insert Table 5 about here]*

Of particular interest, all results from baseline regression remain unchanged. Leverage ratio registered a negative effect on all three measures of innovation is highly significant with correspondent coefficients (t-statistics are in parentheses) -0.656 (-17.2), -1.139 (-16.8), -0.644 (-16.3) in (1), (2), (3) for Lnpat, QCites and TCites as dependent variables. In this test, Long-term Debt is controlled by leverage and Very-long-term Debt. As can be seen from the results, coefficients of lagged Long-term Debt are all significantly negative at the 1% significance level which provides support for the underinvestment theory where long-term debt does not help to mitigate the cost of underinvestment. The use of long-term debt seems to be "safe" and thus firms may have no need to make any effort on the success of "risky" projects such as innovative investment. In some ways, this "phenomena" trends to harm the outcome of corporate innovation. GMM's results on control variables are mainly in line with the baseline's. As we found in the previous model, Firm size, Firm age, Profitability, Liquidity, R&D expenditures and M&B carry the expected signs, Labour productivity, Cash ratio are negatively related to innovation outcomes and all of them are significant at the 1% level. Again, sale growth, dividend and Herfind index and Herfind index squared are not statistically significant.

#### 4.2.3 PVAR results

To control for reserve causality and possible intertemporal interactions between endogenous variables in the study, we use the Panel Vector Autoregressive approach that estimates the two – equation reduced-form model (2) and (3).

*[Insert Table 6 about here]*

In Table 6, we report the results of the model using two variables Lnpat and D25 in column (1), QCites and D25 in column (2), TCites and D25 in column (3) after the fixed effects and the industry-time dummy variables have been removed.

We observe that the impact of the lagged long-term debt D25 to our innovation outputs measures is consistent with all I expected before. This result confirms once again the theory of underinvestment, where long-term debt discourages corporate

[14] By construction, the differences in error term is probably first-order serially correlated even if the original error term is not.

innovation in terms of quality and quantity. Even interested coefficients (t statistics are in parentheses) much lower are found than those I found in the fixed effects regressions (coefficient are from running PVAR results just only -0.028 (-2.6), -0.095 (-3.6) and -0.054 (-4.0) for Lnpat, QCites and TCites, respectively). Other control variables such as Leverage, Firm Size, Firm Age, MBA and R&D expenditures carry the expected signs and their coefficients are statistically significant.

We present graphs of impulse – response functions and 5% error bands generated by Monte Carlo simulation. Figure 5,6,7 report graphs of impulse responses for the model with two variables Lnpat and D25; QCites and D25; TCites and D25, respectively.

*[Insert Figure 5, 6, 7 about here]*

The results of our particular interests are the negative responses of innovation in terms of quantity and quality to a long-term debt shock. On one hand, Figure 5, 6, 7 show a significant negative impact of long-term debt (D25) on innovation: Lnpat (figure 5), QCites (Figure 6) and (TCites (Figure 7). On the other hand, these figures also show the response of long-term debt on the shock of corporate innovation outputs which are not clear. One of the possible reasons for this is that the biggest limitation of PVAR is also found in explaining the non-linear relationship between interest variables. Aghion et al. (2004) finds evidence to show that there is a non-linear relation between debt on the assets ratio and innovative side of firms. Another possibility is that corporate innovation outputs do not have any impact on debt maturity, such as Dang (2011) which shows that debt maturity is unaffected by growth opportunities (proxied by R&D expenses in a robustness check) and thus does not attenuate the negative effect of growth opportunities on leverage.

In the next step, we do an additional robustness check for PVAR by using Very-long-term Debt (D5) as a proxy for debt maturity structure. Untabulated results confirm our hypothesis.

*[Insert Figure 8, 9, 10 about here]*

In Figures 8, 9, 10, we present the impulse – response functions and the 5% error bands generated by Monte Carlo simulation for one lag VAR of Lnpat residuals, QCites residuals and TCites residuals with D5 residuals, respectively. On one hand, we observe that the response of Lnpat to a shock of debt maturity structure (D5, Very-long-term debt) is negative. A similar pattern in the responses of QCites and TCites to

D5 shock is also registered. On the other hand, we note that for the first time in PVAR running results, the reserve response of D5 to corporate innovation's shock is negative and statistically significant.

If we consider that the success of innovative investment is a growth opportunity for the firm, this finding is consistent with empirical research (Barclay and Smith 1995), (Barclay et al. 2003), (Johnson 2003) which find evidence to show that there is a strong negative impact of growth opportunities on debt maturity in the US.

#### 4.2.4 Alternative model specific

In this section, we conduct some additional robustness tests of our empirical findings by using alternative measures of debt maturity structure and innovation proxies.

Firstly, there may be a concern that our results are driven by a mismeasurement in debt maturity structure. To mitigate this concern,we consider an alternative measure of debt maturity such as the proportion of debt matures more than three years (Barclay and Clifford W 1995), (Barclay et al. 2003), (Johnson 2003), (Datta et al. 2005), (Aivazian et al. 2005a). All the previous result remains unchanged.

In the next step, we try again with the proxy for Debt maturity in this case it is the Proportion of Debt which is due in more than one year (D1). Once more, our results hold. Additionally, we calculate the number of the number of Notice of Allowance (NOA) to the patent applicant stating that the patent is pending approval (forthcoming) (Plumlee and Yu 2012) and NOA adjusted as proxies of corporate innovation outputs to mitigate the long time required to obtain the patent officially. Prior to issuing a patent, the US Patent and Technology Office (USPTO) issues a Notice of Allowance (NOA)[15] to the patent applicant stating that the patent is pending approval. The NOA is official recognition that a patent will be issued by the USPTO, with contingent on the applicant paying the required fees within a three-month period[16]. This notification represents favorable information to the patent applicant; the issuance of a NOA declares the USPTO's intention to grant a patent that allows firms to extract stable monopoly rents (Plumlee and Yu 2012). The NOA also represents proprietary information, as the USPTO holds its issuance of a NOA strictly confidential and public announcement of the receipt of a NOA is rare. Thus, we show that NOA and NOA adjusted are valid

[15] http://www.uspto.gov/trademarks
[16] http://www.uspto.gov/web/offices/pac/mpep/s1303.html

proxies for innovation outputs. In untabulated results from running regression with NOA and NOA adjusted, we find that our conclusions do not change.

Finally, we consider several additional robustness checks. For examples, our results hold if we remove the tech bubble (1998-2000) or consider the whole period from 1976 until 2006, however the results are weaker.

**CONCLUSION**

In this section, we would like to come back to our very first research question: How would firms choose a maturity debt structure for enhancing the innovative objectives?

We hypothesize that long-term debt damages corporate innovation in term of quantity and quality. Holmstrom (1989) states that innovative investment tends to take a long time before delivering positive results. They are often risky with a high probability of failure and uncertain returns. In addition, innovation projects require a huge human effort and require different ways of evaluating because of their idiosyncratic characteristics. Due to the high risks and being completely different from the others, investors expect a high return from these innovative projects. We assume that the investment on innovation is fully recognized as a firm's high growth option. As explained from "underinvestment hypothesis", in presence of high growth option, firms act like an agent and principals, who own capital and a potential agency conflict between debt holders and shareholders may be created.

Principals may require a higher premium per the capital provided due to risky and uncertain characteristics of innovative investment and thus firms may bypass investment in positive NPV projects. To deal with this problem, one solution is that using short-term debt contracts to benefit both agents and principals. By doing this, both firms and debt holders can reconsider and make an arrangement on their interest on investment opportunities ex-post. These arguments suggest that the more long-term debt firms use, the less innovative they are.

Our results are consistent with these expectations. There is clear evidence from our models of analysis to show that long-term debt curbs corporate innovation in terms of both quantity and quality. Specifically we find that long-debt is negatively associated with the number of patents and patent citations, suggesting that long-term debt slows down the corporate innovation and shorter maturity of debt enhances the success of innovative investment. All our results hold after using different robustness checks, such as different proxies for debt maturity, corporate innovation, alternative analysis method PVAR instead of GMM, fixed effects.

This study provides a contribution on the literature of corporate capital structure especially on debt maturity structure and corporate innovation. In spite of the fact that numerous studies have been done on the relationship between financing decisions and innovation, there has not been a study on specific debt decisions and the success of innovative investment has never been discovered.

By using a large data set which includes 312,914 observations in the period from 1976 to 2006 covered in the Compustat and a fixed effects identifications strategy, we identify economics mechanism through which financing decisions affect corporate innovation. We show that external financial resources are important for the success of innovative investment especially the debt decisions. Shorter term debt maturity is found significantly and positively relate to the outcomes of innovative investment in term of number of patents and their citations. Indeed, we find evidences to show that long-term debt damages corporate innovation. These findings are consistent with the underinvestment hypothesis which explains why shortening the maturity of outstanding debts helps firms not to forgo the high expected return investment projects (high growth option for firms).

Our findings are important not only for theoretical researchers but also practitioners. On one hand, they refer to the role of resolving the underinvestment problem and putting these solutions to the emerging complicated issues from the relationship between debt maturity structure decisions and outputs of innovative investment. On the other hand, our study gives a managerial implication for managers who have to decide which maturity structure firms should take when they are engaged in innovative investment to reach the highest outcomes from these projects. An important feature of this empirical study is the use of different analysis methods, including fixed effects identification on both time and industry, dynamic panel data estimation (GMM-system) and panel vector autoregressive (PVAR). Together, they allow us to produce a robust result.

What is more, we propose four additional areas to work on the future. Firstly, our difficulty in effectively identifying a suitable proxy to explain corporate innovation which is still open for further discussion and research in future. Secondly, we limit our study to debt maturity structure and corporate innovation. In the next study, it could be possible to expand our study to include debt structure, such as bank debt, secured/unsecured debt, fixed/variable rate debt. A study including debt structure will contribute to the literature and complete the picture about debt financing in corporate innovation. Thirdly, as in any empirical study, mine is potentially subject to some estimation issues, particularly reserve causality. In our research, we used GMM and PVAR to deal with this. However, we believe that we can still work on this issue and discover other techniques to confirm our results in this study. Lastly, the theme on financing corporate innovation is discovered by numerous studies as listed in section 2. Nonetheless, most of them are on developed countries and there are far fewer on developing countries. Thus, we believe that there is still space to discover the relationship between corporate innovation and financing policy especially per via debt channel. In this picture, it is possible to include social-political factors, market conditions and tax systems in the study.

## APPENDIX: VARIABLES DEFINITIONS

| Variables | | Definitions |
|---|---|---|
| **Dependent Variables** | | |
| Patent (raw) | (Lnpat) | Number of patents applied during the year. |
| Patent (adjusted) | (Cnpat) | Number of patents applied during the year adjusted |
| Citation (raw) | | Total number of citations summed across all patents applied by the firm during the year. |
| Qcitation | (QCites) | Total number of citations summed across all patents applied by the firm during the year. Each patent's number of citations is multiplied by the weighting index from Hall, Jaffe and Trajtenberg (2001, 2005). |
| Tcitation | (TCites) | Total number of citations summed across all patents applied by the firm during the year. Each patent's number of citations is divided by the average citation count of all patents in the same technology class and applied in the same year. |
| **Debt maturity structures** | | |
| Long-term | (D25) | Proportion of total debt with maturity longer than 1 year and less than 5 years |
| Short-term | (STD) | Proportion of total debt with maturity less than 1 year |
| $D^2/D$ | (D2) | Proportion of total debt with maturity longer than 2 years |
| $D^3/D$ | (D3) | Proportion of total debt with maturity longer than 3 years |
| Very-long-term | (D5) | Proportion of total debt with maturity longer than 5 years |
| **Other variables** | | |
| Firm age | | Number of years since the firm entered CRSP |
| Size | | Ln(Assets). |
| Leverage | | (Short-term debt + Long-term debt) / Assets. |
| Liquidity | | the assets liquidity/total assets |
| MB | | Market value of equity/Book value of equity |
| Labour productivity | | Net property, plant, and equipment per employee in thousands (PPE/#Employees) |
| ROA | | Operating income before depreciation and amortization (EBITDA)/Assets |
| Sales growth | | Change in net sales scaled by the lagged net sales |
| R&D/Assets | | R&D expenses/Assets. Missing R&D expenses are treated as zero. |
| Cash ratio | | Cash scaled by total assets. |
| Dividend payer | | a dummy variable, 1 if a firm is a cash dividend payer or 0 if a firm is not a cash dividend payer in the year |
| Herfindahl | | Industry Herfindahl index based on all Compustat firms, where industries are defined by 3-digit SIC. |
| Herfindahl_sq | | Industry Herfindahl index square |

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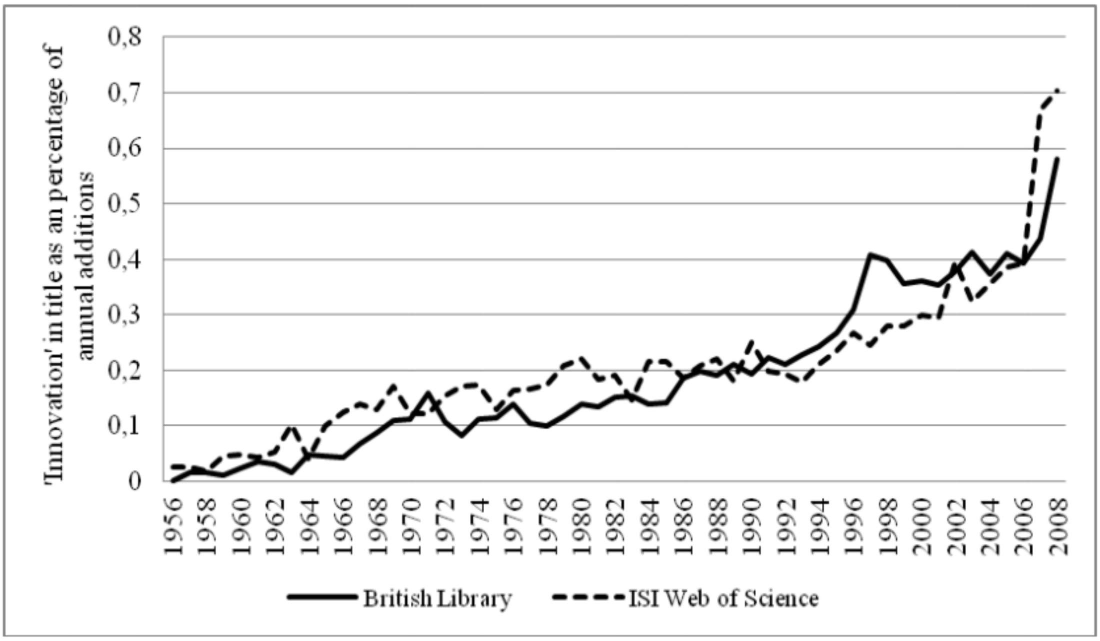
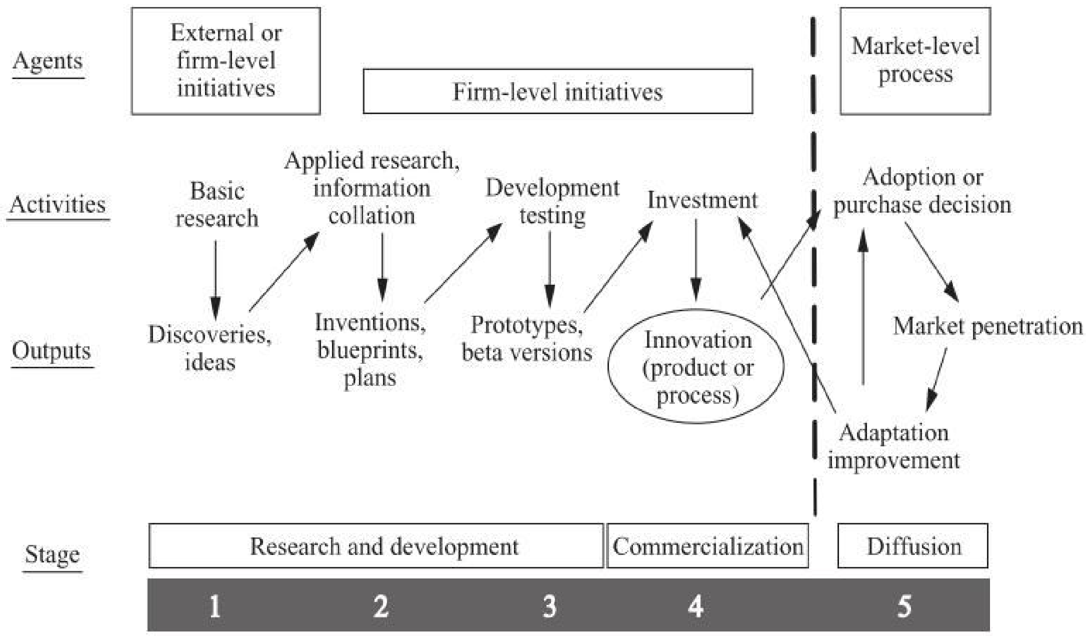
*Figure 1: Growth of literature on innovation*




Source: Fagerberg, Fosaas and Sapprasert (2012)

*Figure 2: The stages of innovation process*




Source: Greenhalgh, C., & Rogers, M. (2010). The Nature and Importance of Innovation. In *Innovation, Intellectual Property, and Economic Growth* (pp. 3–311).

*Figure 3: Mean values of number of patents (raw) 1976-2003*

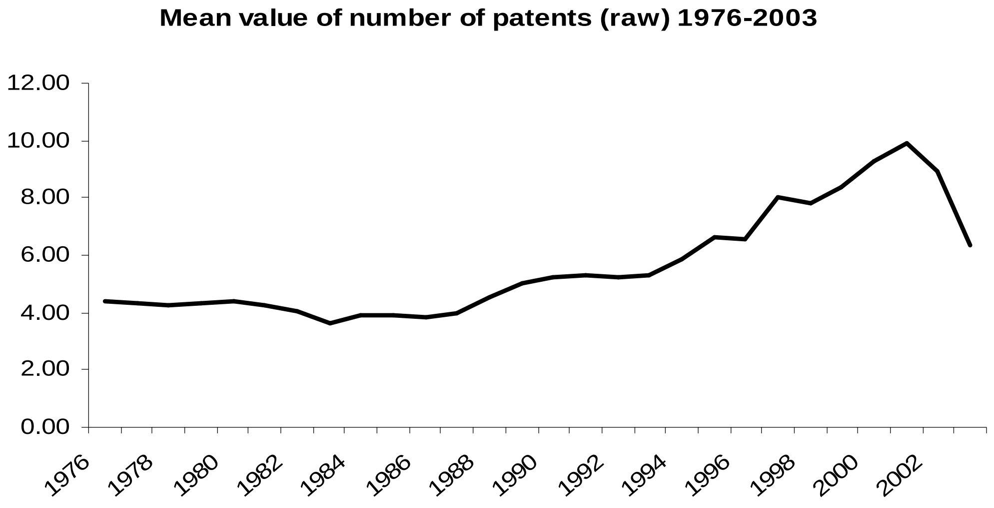



*Figure 4: Debt maturity structure (mean value) U.S firms 1976-2003*

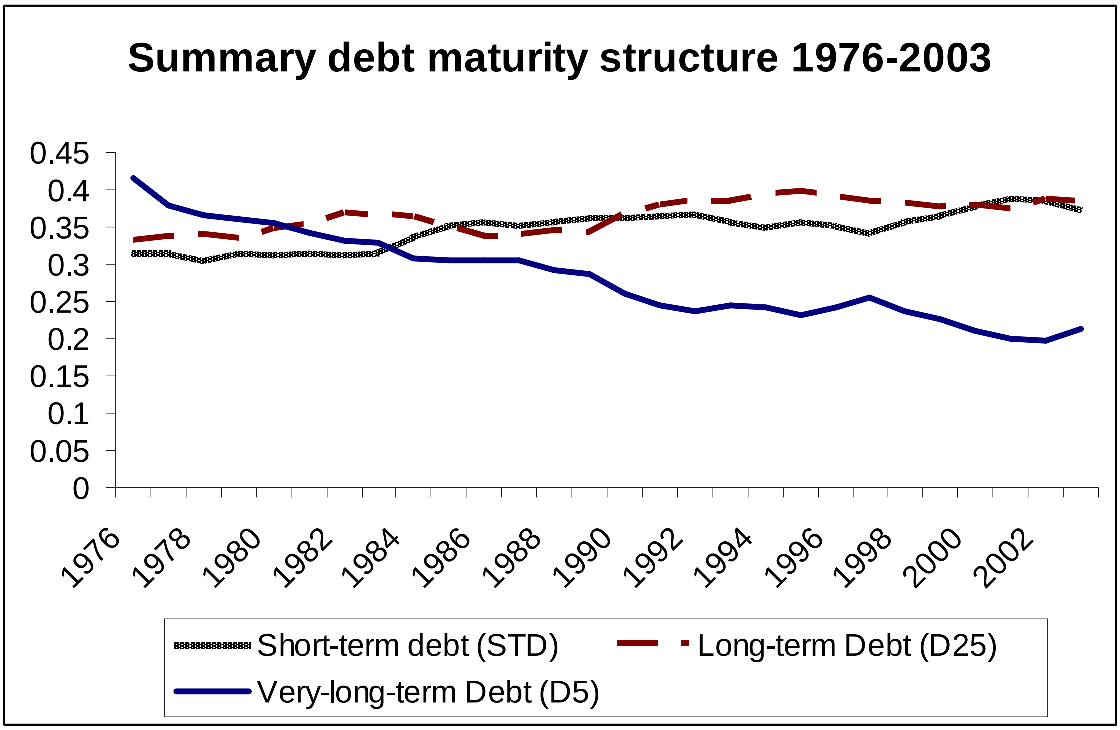


**Figure 5: Impulse – responses for 1 lag VAR of Residuals of NPatents (Lnpat) and Longterm debt (D25)**

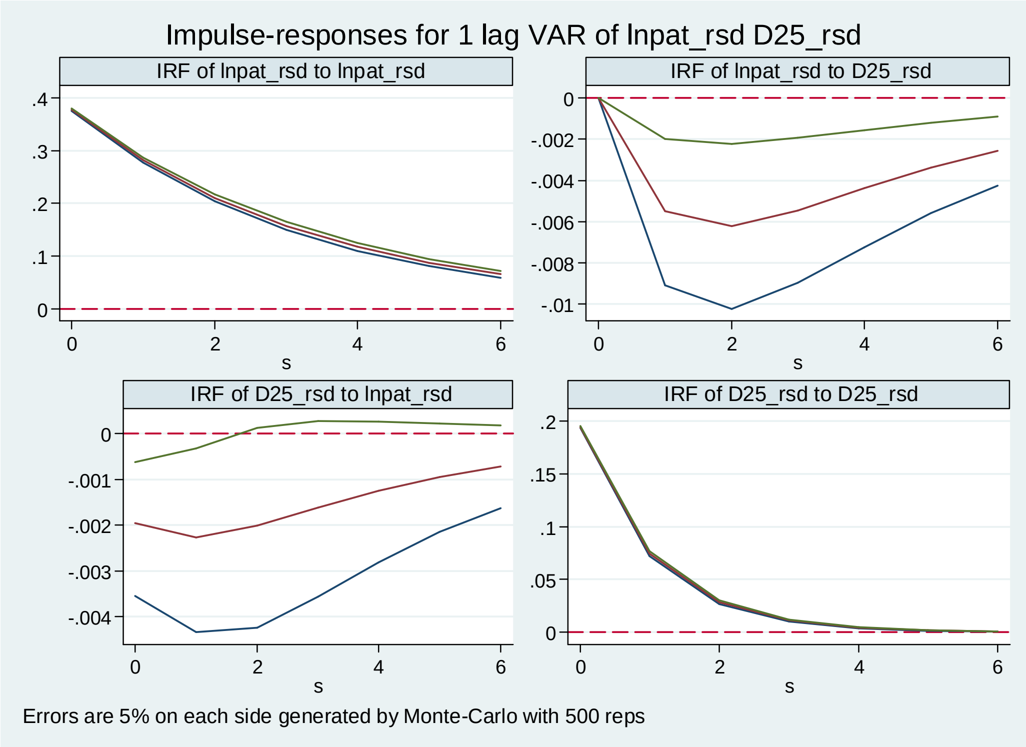



*Figure 6: Impulse – responses for 1 lag VAR of Residuals of QCites (QCites) and Long-term debt (D25)*

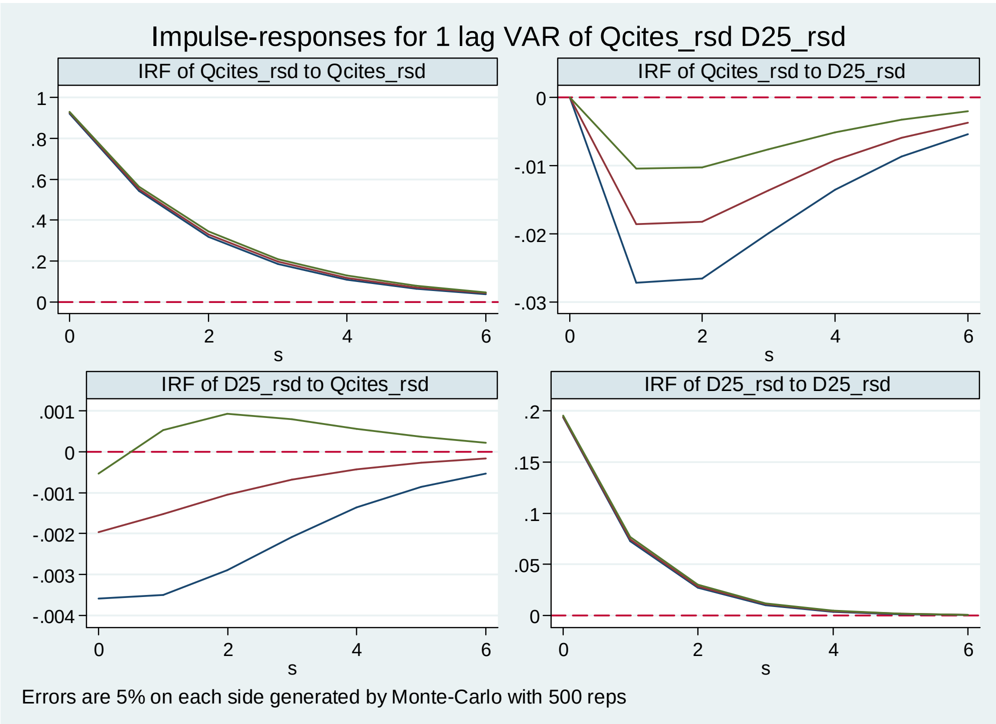


*Figure 7: Impulse – responses for 1 lag VAR of Residuals of TCites (TCites) and Long-term debt (D25)*

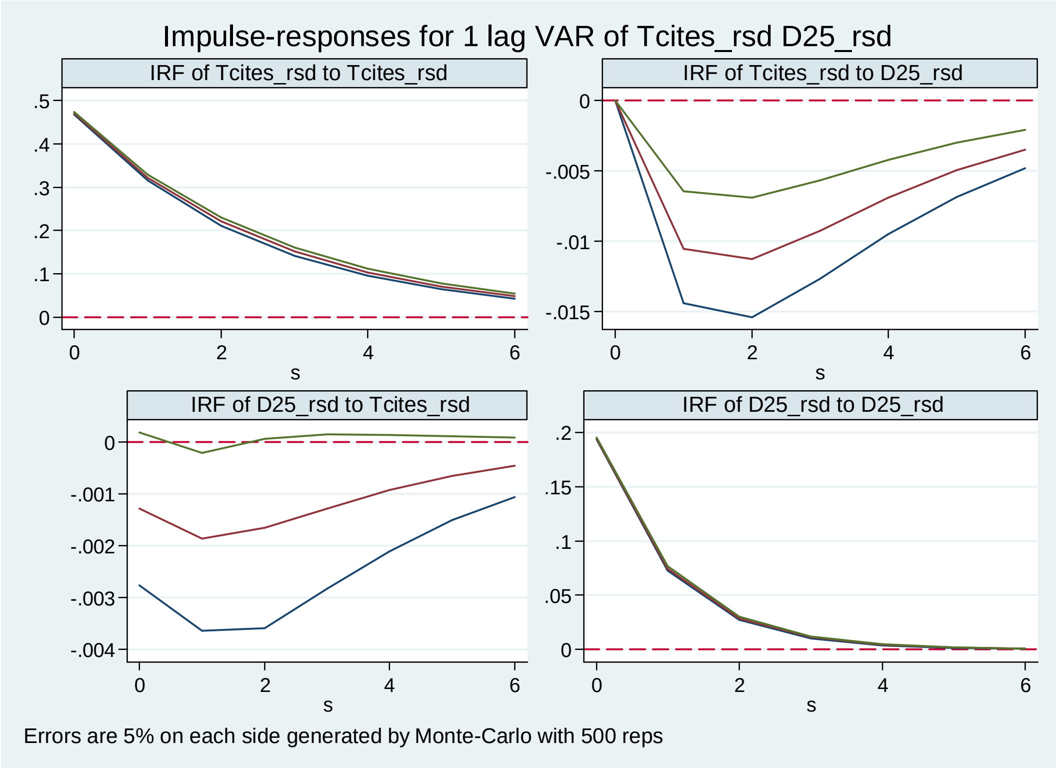



*Figure 8: Impulse – responses for 1 lag VAR of Residuals of NPatents (Lnpat) and Very-long-term debt (D5)*

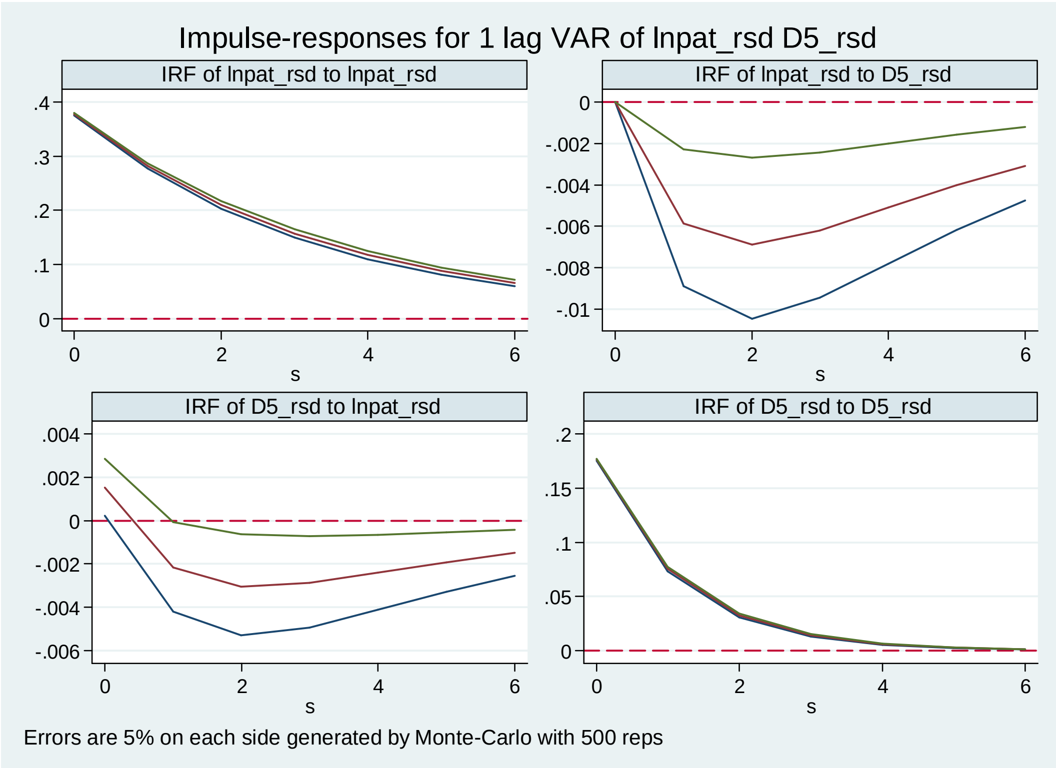


*Figure 9: Impulse – responses for 1 lag VAR of Residuals of QCites (QCites) and Very-long-term debt (D5)*

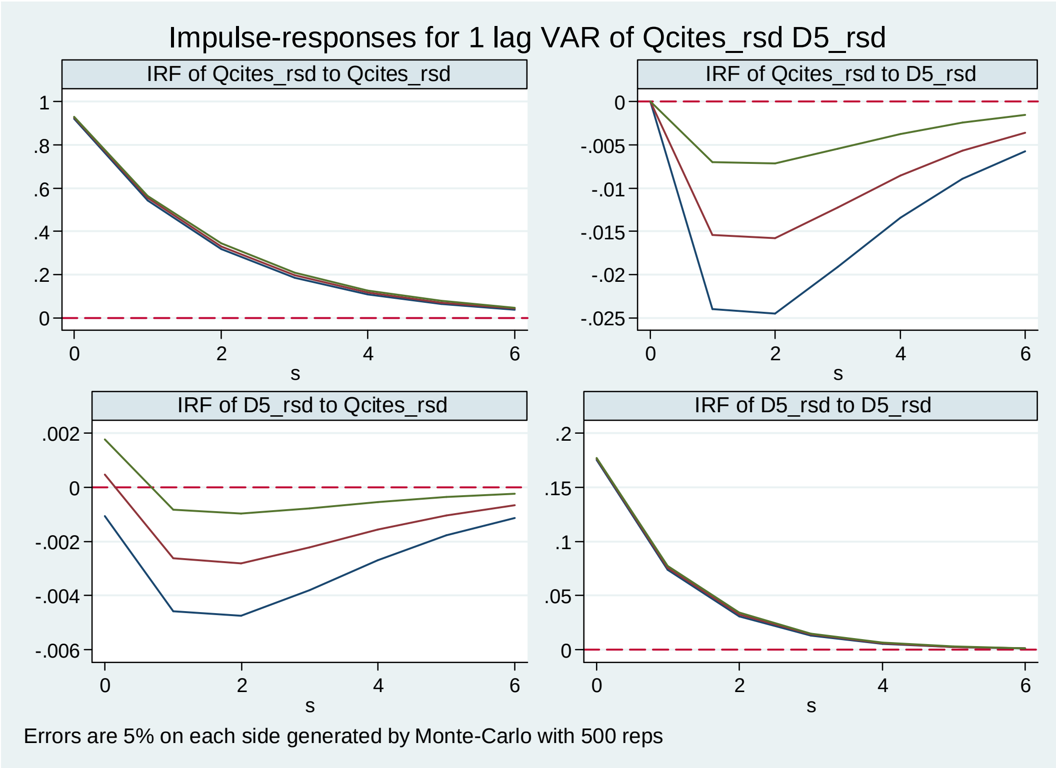



*Figure 10: Impulse – responses for 1 lag VAR of Residuals of TCites (TCites) and Very-long-term debt (D5)*

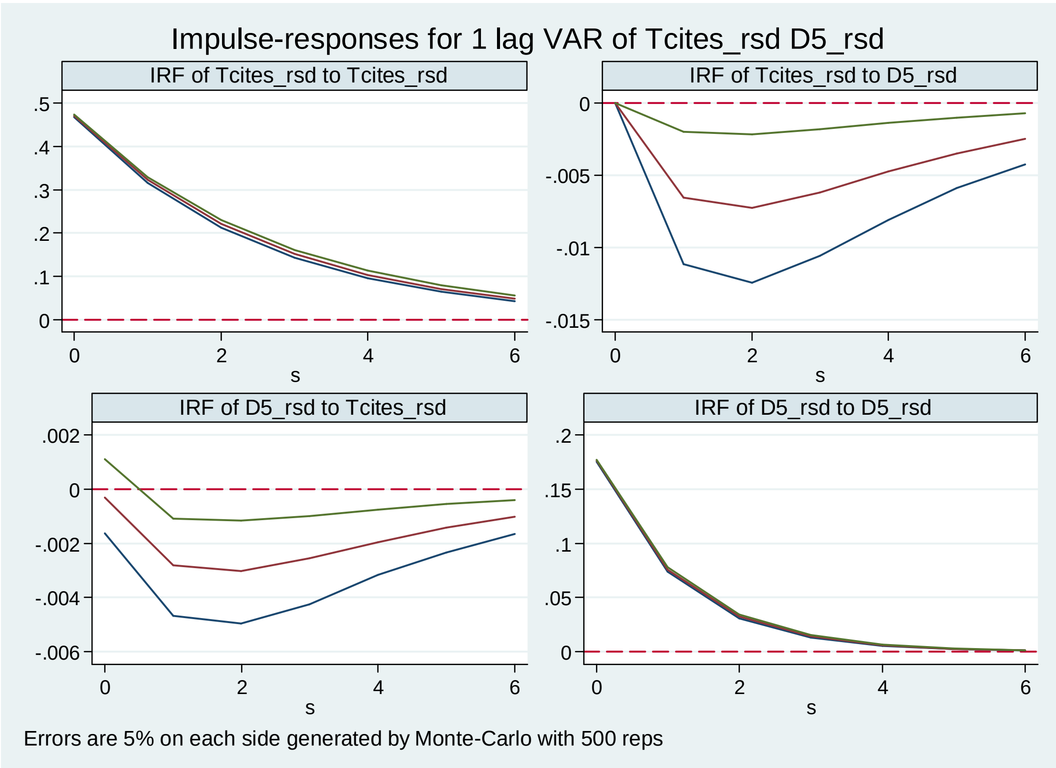


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*Table 1. Summary statistics*

The sample consists of firms covered by both Compustat and the NBER Patent and Citation Database between 1976 and 2003.

| Variables | Mean (1) | Standard Deviation (2) | Q1 (3) | Median (4) | Q3 (5) |
|---|---|---|---|---|---|
| Panel A: Innovation measures | | | | | |
| Patents (Raw) | 5.93 | 60.41 | 0.00 | 0.00 | 0.00 |
| Patents (Adjusted) | 0.20 | 1.91 | 0.00 | 0.00 | 0.00 |
| Citations (Raw) | 50.53 | 541.36 | 0.00 | 0.00 | 0.00 |
| Q_Citations | 6.64 | 66.80 | 0.00 | 0.00 | 0.00 |
| T_Citations | 86.03 | 1001.04 | 0.00 | 0.00 | 0.00 |
| Panel B: Debt maturity structure measures | | | | | |
| Short-term debt | 0.35 | 0.34 | 0.07 | 0.23 | 0.57 |
| Long-term debt | 0.65 | 0.34 | 0.42 | 0.77 | 0.93 |
| Debt due in>2years | 0.51 | 0.35 | 0.15 | 0.57 | 0.82 |
| Debt due in>3years | 0.41 | 0.34 | 0.04 | 0.41 | 0.72 |
| Debt due in>4years | 0.34 | 0.32 | 0.00 | 0.29 | 0.61 |
| Debt due in>5years | 0.28 | 0.30 | 0.00 | 0.17 | 0.51 |
| Leverage | 0.25 | 0.22 | 0.06 | 0.22 | 0.39 |
| Panel C: Firm characteristics | | | | | |
| Firm_size | 1075.10 | 7076.97 | 10.19 | 51.18 | 279.29 |
| Profitability | -0.05 | 0.44 | -0.04 | 0.06 | 0.12 |
| Cash Ratio | 0.16 | 0.21 | 0.02 | 0.07 | 0.21 |
| Liquidity | 0.51 | 0.25 | 0.30 | 0.53 | 0.71 |
| Firm age | 2.04 | 1.03 | 1.39 | 2.08 | 2.77 |
| R&D | 0.04 | 0.11 | 0.00 | 0.00 | 0.03 |
| Sale growth | 0.26 | 0.86 | -0.03 | 0.10 | 0.28 |
| Dividend payer | 0.31 | 0.46 | 0.00 | 0.00 | 1.00 |
| MB | 2.36 | 3.53 | 1.01 | 1.35 | 2.18 |
| Labour productivity | 4.67 | 0.98 | 4.10 | 4.68 | 5.24 |
| Herfind index | 0.21 | 0.19 | 0.09 | 0.15 | 0.25 |
| Herfind index squared | 0.08 | 0.17 | 0.01 | 0.02 | 0.06 |
| Volatility | 3.57 | 8.13 | -0.00 | 1.54 | 4.27 |
| Abnormal earnings | 0.05 | 0.50 | -0.04 | 0.01 | 0.05 |
| Tax rate | 0.23 | 0.28 | 0.00 | 0.30 | 0.41 |

*Table 2: Pearson correlation matrix*

The sample consists of firms covered by both Compustat and the NBER Patent and Citation Database between 1976 and 2003.
The detailed definitions of variables are described in Appendix A.
All variables are winsorized at the 1% level at both tails of distribution. Dollar values are converted into 2000 constant dollars using the GDP deflator. The symbol (*) denotes significance at the 5% level or better.

| | Lnpat | QCites | TCites | D25 | Leve-rage | Firm size | Prof. | Cash ratio | Liqui. | Firm_age | R_D | Sale growth | Dividend | MB | Lab. produ. | Herf-index | Herf-SQ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lnpat | 1.000 | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| QCites | 0.944* | 1.000 | | | | | | | | | | | | | | | |
| | 0.000 | | | | | | | | | | | | | | | | |
| TCites | 0.966* | 0.968* | 1.000 | | | | | | | | | | | | | | |
| | 0.000 | 0.000 | | | | | | | | | | | | | | | |
| D25 | -0.084* | -0.081* | -0.084* | 1.000 | | | | | | | | | | | | | |
| | 0.000 | 0.000 | 0.000 | | | | | | | | | | | | | | |
| Leverage | -0.115* | -0.127* | -0.113* | 0.056* | 1.000 | | | | | | | | | | | | |
| | 0.000 | 0.000 | 0.000 | 0.000 | | | | | | | | | | | | | |
| Firm_size | 0.466* | 0.411* | 0.440* | -0.029* | 0.063* | 1.000 | | | | | | | | | | | |
| | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | | | | | | | | | | | |
| Profitabil~y | 0.101* | 0.104* | 0.101* | 0.074* | -0.066* | 0.304* | 1.000 | | | | | | | | | | |
| | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | | | | | | | | | | |
| Cash_ratio | 0.017* | 0.026* | 0.016* | -0.078* | -0.341* | -0.164* | -0.199* | 1.000 | | | | | | | | | |
| | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | | | | | | | | | |
| Liquidity | 0.015* | 0.051* | 0.021* | -0.127* | -0.311* | -0.308* | 0.009* | 0.375* | 1.000 | | | | | | | | |
| | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.012 | 0.000 | | | | | | | | | |
| Firm_age | 0.297* | 0.270* | 0.281* | -0.045* | 0.001 | 0.405* | 0.155* | -0.228* | -0.081* | 1.000 | | | | | | | |
| | 0.000 | 0.000 | 0.000 | 0.000 | 0.886 | 0.000 | 0.000 | 0.000 | 0.000 | | | | | | | | |
| R_D | 0.133* | 0.144* | 0.128* | -0.069* | -0.161* | -0.181* | -0.492* | 0.355* | 0.222* | -0.120* | 1.000 | | | | | | |
| | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | | | | | | |
| Sale_growth | -0.047* | -0.041* | -0.042* | -0.001 | -0.018* | -0.081* | -0.071* | 0.145* | 0.005 | -0.227* | 0.077* | 1.000 | | | | | |
| | 0.000 | 0.000 | 0.000 | 0.748 | 0.000 | 0.000 | 0.000 | 0.000 | 0.134 | 0.000 | 0.000 | | | | | | |
| Dividend | 0.259* | 0.243* | 0.245* | -0.063* | -0.106* | 0.459* | 0.279* | -0.181* | -0.071* | 0.384* | -0.193* | -0.129* | 1.000 | | | | |
| | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | | | | |
| MBA | 0.020* | 0.025* | 0.020* | -0.052* | -0.115* | -0.154* | -0.321* | 0.290* | 0.071* | -0.189* | 0.339* | 0.199* | -0.149* | 1.000 | | | |
| | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | | | |
| Labour_pro~y | 0.072* | 0.046* | 0.060* | 0.016* | 0.002 | 0.281* | 0.119* | -0.053* | -0.014* | 0.062* | -0.065* | -0.021* | -0.001 | -0.047* | 1.000 | | |
| | 0.000 | 0.000 | 0.000 | 0.000 | 0.596 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.839 | 0.000 | | | |
| Herfind_in~x | 0.001 | 0.009* | 0.004 | -0.001 | 0.008* | -0.006 | 0.053* | -0.078* | 0.026* | 0.046* | -0.108* | -0.027* | 0.074* | -0.043* | -0.003 | 1.000 | |
| | 0.710 | 0.007 | 0.258 | 0.731 | 0.024 | 0.096 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.361 | | |
| Herfind_SQ | -0.010* | -0.006 | -0.008* | -0.001 | 0.000 | -0.007 | 0.027* | -0.037* | 0.000 | 0.021* | -0.073* | -0.013* | 0.048* | -0.018* | -0.003 | 0.938* | 1.000 |
| | 0.006 | 0.094 | 0.025 | 0.717 | 0.908 | 0.078 | 0.000 | 0.000 | 0.887 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.300 | 0.000 | |

*Table 3: OLS with fixed effect on the time and industry*

This table reports OLS with fixed effect on the time and industry regression of innovation outputs defined as Lnpat (Log of one plus number of patents), Cnpat (Log of one plus number of patents adjusted), QCites (Log of total number of QCitation) and TCites (Log of number of TCitation). The results show the effects of leverage and control variables on corporate innovation outputs.
The sample consists of observations on COMPUSTAT firms from 1976 to 2003. Financial industries (SIC codes 6000-6999) and utilities (SIC codes 4900-4999) are omitted. Refer to Appendix A for variables definitions.
The symbols ***, **, and * denote significance at the 1%, 5% and 10% levels, respectively.

| | Lnpat | CnPat | QCites | TCites |
|---|---|---|---|---|
| | OLS | OLS | OLS | OLS |
| | (1) | (2) | (3) | (4) |
| Leverage | -0.341*** | -0.081*** | -0.668*** | -0.363*** |
| | (-10.8) | (-9.3) | (-11.8) | (-10.9) |
| Firm_size | 0.266*** | 0.065*** | 0.457*** | 0.266*** |
| | (33.1) | (23.2) | (37.0) | (32.1) |
| Profitabil~y | -0.022 | -0.041*** | 0.083* | -0.017 |
| | (-1.0) | (-6.4) | (2.0) | (-0.7) |
| Cash_ratio | 0.190*** | 0.011 | 0.395*** | 0.198*** |
| | (4.5) | (1.1) | (5.0) | (4.4) |
| Liquidity | -0.031 | -0.005 | 0.003 | -0.044 |
| | (-0.7) | (-0.4) | (0.0) | (-0.9) |
| Firm_age | 0.097*** | 0.027*** | 0.158*** | 0.096*** |
| | (11.0) | (10.4) | (10.6) | (10.5) |
| R_D | 1.281*** | 0.178*** | 2.681*** | 1.245*** |
| | (16.1) | (9.1) | (17.0) | (14.3) |
| Sale_growth | 0.004 | 0.001 | 0.014* | 0.008* |
| | (1.3) | (1.0) | (2.1) | (2.3) |
| Dividend | -0.024 | -0.013** | -0.060 | -0.048* |
| | (-1.3) | (-2.8) | (-1.8) | (-2.5) |
| MBA | 0.028*** | 0.005*** | 0.054*** | 0.030*** |
| | (12.5) | (9.8) | (12.9) | (12.5) |
| Labour_pro~y | -0.020* | -0.002 | -0.042** | -0.015 |
| | (-2.3) | (-0.9) | (-2.7) | (-1.7) |
| Herfind_in~x | -0.004 | -0.005 | 0.100 | 0.016 |
| | (-0.0) | (-0.1) | (0.4) | (0.1) |
| Herfind_SQ | 0.162 | 0.040 | 0.179 | 0.138 |
| | (1.1) | (0.9) | (0.7) | (0.9) |
| _cons | -0.441* | -0.153*** | -0.553 | -0.529** |
| | (-2.6) | (-4.6) | (-1.6) | (-3.2) |
| Y/Industry f.e | Yes | Yes | Yes | Yes |
| Adjusted R_square | 0.388 | 0.325 | 0.354 | 0.351 |
| Sample size | 108099 | 108099 | 108099 | 108099 |

*Table 4: OLS with fixed effect on the time & industry*

Effects of Long-term Debt (D25) on innovation outputs controlled by Leverage, Very-long-term Debt and firms characteristics

This table reports OLS with fixed effects on the time & industry regression of innovation outputs defined as Lnpat (Log of one plus number of patents), QCites (Log of one plus QCitation) and TCites (Log of one plus number of TCitation). The results show the effects of long-term debt controlled by Leverage, Very-long-term debt and other firm's characteristic variables on the corporate innovation outputs.

The sample consists of observations on COMPUSTAT firms from 1976 to 2003. Financial industries (SIC codes 6000-6999) and utilities (SIC codes 4900-4999) are omitted. Refer to Appendix A for variables definitions.

The symbols ***, **, and * denote significance at the 1%, 5% and 10% levels, respectively.

INNOVATION/LONG-TERM DEBT (D25) CONTROLLED BY LEVERAGE & VERY-LONG-TERM DEBT
TIME & INDUSTRY FIXED EFFECTS

| | Lnpat | QCites | TCites |
|---|---|---|---|
| | OLS | OLS | OLS |
| | (1) | (2) | (3) |
| Leverage | -0.316*** | -0.660*** | -0.333*** |
| | (-8.0) | (-9.5) | (-8.1) |
| D25 | -0.206*** | -0.274*** | -0.208*** |
| | (-9.2) | (-6.9) | (-8.8) |
| D5 | -0.269*** | -0.337*** | -0.272*** |
| | (-7.6) | (-5.8) | (-7.3) |
| Firm_size | 0.290*** | 0.485*** | 0.290*** |
| | (30.0) | (33.2) | (29.1) |
| Profitabil~y | 0.014 | 0.131* | 0.024 |
| | (0.5) | (2.4) | (0.8) |
| Cash_ratio | 0.280*** | 0.468*** | 0.282*** |
| | (4.9) | (4.6) | (4.7) |
| Liquidity | -0.074 | -0.020 | -0.090 |
| | (-1.3) | (-0.2) | (-1.5) |
| Firm_age | 0.109*** | 0.176*** | 0.107*** |
| | (10.6) | (10.3) | (10.2) |
| R_D | 1.630*** | 3.304*** | 1.663*** |
| | (13.5) | (14.3) | (12.5) |
| Sale_growth | -0.001 | 0.001 | 0.002 |
| | (-0.3) | (0.2) | (0.5) |
| Dividend | -0.007 | -0.009 | -0.026 |
| | (-0.3) | (-0.2) | (-1.2) |
| MBA | 0.030*** | 0.054*** | 0.030*** |
| | (9.7) | (9.4) | (9.2) |
| Labour_pro~y | -0.027* | -0.056** | -0.025* |
| | (-2.3) | (-2.9) | (-2.1) |
| Herfind_in~x | 0.021 | 0.149 | 0.039 |
| | (0.1) | (0.6) | (0.3) |
| Herfind_SQ | 0.110 | 0.083 | 0.094 |
| | (0.6) | (0.3) | (0.5) |
| _cons | -0.329 | -0.301 | -0.408* |
| | (-1.8) | (-0.8) | (-2.1) |
| year/.. ef~s | Yes | Yes | Yes |
| Adjusted R_square | 0.419 | 0.388 | 0.386 |
| Sample size | 73704 | 73704 | 73704 |

*Table 5: Dynamic panel data estimations, system_GMM results*

Effects of Long-term Debt (D25) on innovation outputs controlled by Leverage, Very-long-term Debt and firm's characteristics

This table reports GMM system where dependent variables are innovation outputs and defined as Lnpat (Log of one plus number of patents), QCites (Log of one plus QCitation) and TCites (Log of one plus number of TCitation). The results show the effects of long-term debt controlled by Leverage, Very-long-term debt and other firm's characteristic variables on the corporate innovation outputs.

The instruments for the transformed equations include GMM lags 2 years through 5 years of the endogenous variables. The instruments for the level equations include year dummies, and GMM differences (lag 1 year) for the endogenous variables. The t-statistics in parentheses are calculated from the Huber/White/Sandwich heteroskedastic consistent errors.

The sample consists of observations on COMPUSTAT firms from 1976 to 2003. Financial industries (SIC codes 6000-6999) and utilities (SIC codes 4900-4999) are omitted. Refer to Appendix A for variables definitions.

The symbols ***, **, and * denote significance at the 1%, 5% and 10% levels, respectively.

INNOVATION/LONG-TERM DEBT (D25) CONTROLLED BY LEVERAGE & VERY-LONG-TERM DEBT

| | Lnpat | QCites | TCites |
|---|---|---|---|
| | GMM-sys | GMM-sys | GMM-sys |
| | (1) | (2) | (3) |
| Leverage | -0.656*** | -1.139*** | -0.644*** |
| | (-17.2) | (-16.8) | (-16.3) |
| D25 | -0.189*** | -0.281*** | -0.187*** |
| | (-9.9) | (-7.9) | (-9.5) |
| D5 | -0.032*** | -0.052* | -0.025** |
| | (-3.6) | (-2.8) | (-2.58) |
| Firm_size | 0.246*** | 0.485*** | 0.243*** |
| | (25.5) | (33.2) | (24.7) |
| Profitabil~y | 0.203*** | 0.518*** | 0.229 |
| | (6.9) | (9.2) | (7.4) |
| Cash_ratio | -0.223*** | 0.484*** | -0.240*** |
| | (-4.5) | (-5.2) | (-4.67) |
| Liquidity | 0.259*** | 0.725*** | 0.292*** |
| | (6.4) | (10.2) | (7.1) |
| Firm_age | 0.099*** | 0.174*** | 0.096*** |
| | (9.0) | (9.3) | (8.6) |
| R_D | 2.785*** | 5.449*** | 32.793*** |
| | (19.9) | (20.1) | (18.3) |
| Sale_growth | -0.005 | -0.005 | -0.003 |
| | (-1.2) | (-0.6) | (-0.8) |
| Dividend | -0.009 | 0.119 | -0.018 |
| | (-0.5) | (0.3) | (-0.92) |
| MBA | 0.011*** | 0.025*** | 0.012*** |
| | (3.75) | (4.2) | (3.8) |
| Labour_pro~y | -0.169*** | -0.303** | -0.174*** |
| | (-18.4) | (-19.71) | (-18.5) |
| Herfind_in~x | 0.025 | 0.657** | 0.146 |
| | (0.17) | (2.6) | (0.97) |
| Herfind_SQ | -0.071 | -0.782** | -0.204 |
| | (-0.4) | (-2.5) | (-1.1) |
| Sample size | 46323 | 46323 | 46323 |
| p-value for Hansen test of overid. | 0.207 | 0.104 | 0.095 |
| Arellano-Bond-AR(1) | 0.000 | 0.000 | 0.000 |
| Arellano-Bond-AR(2) | 0.407 | 0.188 | 0.112 |

***Table 6: Panel Vector Autoregressive (PVAR) Model Analysis***

**Innovation/Long-term Debt (D25) controlled by Leverage and Very-long-term Debt (D5)**

This table reports Panel Vector Autoregressive (PVAR) Model results. Dependent variables are Lnpat (Log of one plus number of patents), QCites (Log of one plus QCitation) and TCites (Log of one plus number of TCitation).

Firm fixed effects are removed by transforming all variables in the model in deviations from forward means. The lagged values of regressors are used as instruments to estimate the coefficients with the generalized method of moment (GMM). Year fixed effects are removed by subtracting the mean value of each variable computed of each year. Z-statistics are in parentheses.

The sample consists of observations on COMPUSTAT firms from 1976 to 2003. Financial industries (SIC codes 6000-6999) and utilities (SIC codes 4900-4999) are omitted. Refer to Appendix A for variables definitions.

The symbols ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

INNOVATION/LONGTERM DEBT (D25) CONTROLLED BY LEVERAGE & VERY-LONG-TERM DEBT

| | $Lnpat_t$ | $QCites_t$ | $TCites_t$ |
|---|---|---|---|
| | b/z | b/z | b/z |
| $Lnpat_{t-1}$ | 0.746*** | | |
| | (100.5) | | |
| $QCites_{t-1}$ | | 0.597*** | |
| | | (82.2) | |
| $TCites_{t-1}$ | | | 0.684*** |
| | | | (76.5) |
| $D25_{t-1}$ | -0.028** | -0.095*** | -0.054*** |
| | (-2.6) | (-3.6) | (-4.0) |
| $Leverage_{t-1}$ | -0.187*** | -0.375*** | -0.178*** |
| | (-8.3) | (-7.4) | (-6.8) |
| $D5_{t-1}$ | -0.005 | -0.018 | -0.007 |
| | (-0.6) | (-0.9) | (-0.7) |
| $Firm\_size_{t-1}$ | 0.164*** | 0.254*** | 0.152*** |
| | (26.1) | (20.2) | (21.7) |
| $Profitability_{t-1}$ | 0.011 | 0.102 | 0.028 |
| | (0.4) | (1.6) | (0.9) |
| $Cash\_ratio_{t-1}$ | 0.026 | -0.077 | 0.003 |
| | (0.7) | (-0.9) | (0.1) |
| $Liquidity_{t-1}$ | 0.043 | 0.256*** | 0.091* |
| | (1.3) | (3.6) | (2.5) |
| $Firm\_age_{t-1}$ | 0.060*** | 0.129*** | 0.066*** |
| | (9.6) | (9.6) | (9.5) |
| $R\_D_{t-1}$ | 1.221*** | 2.803*** | 1.478*** |
| | (9.3) | (9.4) | (9.6) |
| $Sale\_growth_{t-1}$ | -0.009 | -0.017 | -0.008 |
| | (-1.6) | (-1.3) | (-1.2) |
| $Dividend_{t-1}$ | 0.015 | -0.007 | -0.004 |
| | (1.5) | (-0.3) | (-0.3) |
| $MBA_{t-1}$ | 0.024*** | 0.030*** | 0.018*** |
| | (7.2) | (3.8) | (4.5) |
| $Labour\_prod_{.t-1}$ | -0.007 | -0.049*** | -0.018* |
| | (-1.0) | (-3.4) | (-2.5) |
| $Herfind\_index_{t-1}$ | 0.025 | 0.219 | 0.011 |
| | (0.3) | (1.3) | (0.1) |
| $Herfind\_SQ_{t-1}$ | 0.000 | -0.223 | 0.024 |
| | (0.0) | (-1.2) | (0.2) |
| Adjusted_R~e | 0.854 | 0.780 | 0.816 |
| Sample_size | 36557 | 36557 | 36557 |

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