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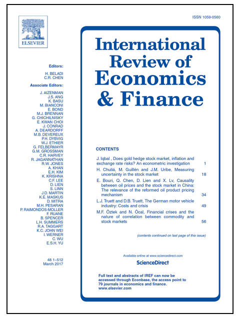

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The determinants of R&D smoothing with asset sales: Evidence from R&D-intensive firms in China

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Abstract

Research and development (R&D)-intensive firms have strong incentives to maintain a smooth path for their R&D investments; otherwise, they will incur high adjustment costs. Examining data covering 2009 to 2016, we find that Chinese R&D-intensive firms, especially those with high innovation efficiency, tend to sell operating and financial assets to protect their value-enhancing R&D investments. However, financial constraints have adverse impacts on R&D smoothing with asset sales unless the firms have high innovation efficiency. The results suggest that innovation efficiency offers R&D-intensive firms, even financially constrained ones, a strong motivation to covert asset sales proceeds into R&D inputs, as the proceeds from asset sales provide a less-costly substitute for external financing. Given the importance of R&D for economic growth and the limited external financing opportunities in emerging capital markets like China, our findings reveal new insights regarding R&D financing.

JEL classification: O32; C23; G34

Keywords: R&D financing; asset sale; innovation efficiency; financial constraint

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Abstract

Research and development (R&D)-intensive firms have strong incentives to maintain a smooth path for their R&D investments; otherwise, they will incur high adjustment costs. Examining data covering 2009 to 2016, we find that Chinese R&D-intensive firms, especially those with high innovation efficiency, tend to sell operating and financial assets to protect their value-enhancing R&D investments. However, financial constraints have adverse impacts on R&D smoothing with asset sales unless the firms have high innovation efficiency. The results suggest that innovation efficiency offers R&D-intensive firms, even financially constrained ones, a strong motivation to covert asset sales proceeds into R&D inputs, as the proceeds from asset sales provide a less-costly substitute for external financing. Given the importance of R&D for economic growth and the limited external financing opportunities in emerging capital markets like China, our findings reveal new insights regarding R&D financing.

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1. Introduction

It is widely argued in the literature that research and development (R&D)-driven innovation is essential for productivity, economic growth and job creations (Solow, 1957; Grossman and Helpman, 1991; Coad, 2019). However, discontinued (or suspended) R&D investments are generally subject to a variety of adjustment costs, such as firing or rehiring costs for highly-trained employees, sunk costs, and time-compression diseconomies (Borisova and Brown, 2013; Brown and Petersen, 2015; Kang et al., 2017). It is thus strategically important for R&D-intensive firms to maintain a smooth path for their R&D investments.

However, R&D activity is susceptible to financial constraints owing to high uncertainty, asymmetric information, and limited collateral value (David et al., 2000; Hall, 2002; Brown et al., 2012). On the one hand, financially constrained firms are more likely to reject or scale down their innovative projects (Campello et al., 2010; Zhang, 2015), as financial constraints are generally believed to have negative effects on firms' innovation activities (Howell, 2016; Pellegrinoa et al., 2017).[1] As pointed out by Zhang(2015), for example, that R&D-intensive firms are more inclined to discontinue or suspend their R&D projects when facing severe financial constraints.

On the other hand, R&D-intensive firms may choose to protect their R&D investments through financing asset sales if they are financially constrained.[2] The proceeds from asset sales provide a less-costly substitute, especially when alternative sources of financing are either unavailable or too expensive (Lang et al., 1995; Shleifer and Vishny, 1992). In other words, financially constrained firms may choose to transfer cash inflows from financing asset sales to protect their value-enhancing R&D investment, which would otherwise be lost owing to high financing costs (Borisova and Brown, 2013; Brown and Petersen, 2015).

[1] Several studies, including Bhagat and Welch(1995), Stephen et al.(2003), Hoegl et al.(2008), and Pellegrinoa and Savona(2017), find that the relationship between financial constraints and innovation activities depends on market conditions.

[2] Arnold et al. (2018) define assets sale for financing as financing assets sale, while Brown and Petersen (2015) point out that asset sales provide a way of raising fund to finance new investment opportunities or meet liquidity needs. In this study, financing assets sale includes both operating assets sale and financial assets sale. According to Chinese Accounting Standards (CASs), operating assets are assets such as property and equipment that a company uses to produce its goods and services, rather than the goods or services that it sells. By contrast, financial assets mainly include tradable financial assets (short-term financial assets), held-to-maturity investments, available-for-sale financial assets, and long-term equity investments.

In practice, financing asset sales are substantial (Edmans and Mann, 2019). An exhaustive survey conducted by Campello et al. (2010) shows that most financially constrained firms in the United States (US), Europe, and Asia engaged in asset sales to fund their operations during the recent global financial crisis. Similarly, Arnold et al. (2018) note that the average proceeds of fixed asset sales for US manufacturing firms in COMPUSTAT were about 44% of their net average amount of newly-issued equity from 1971 to 2010. Furthermore, Hovakimian and Titman (2006) and Borisova and Brown(2013) find that the proceeds from asset sales significantly affect the investment expenditures of financially constrained firms. In addition, Desai and Gupta (2019) show that the average value of financing asset sales accounts for 4.5% of total assets, while that of the financing by security issuance takes 12.3% of total assets .

Nevertheless, how to convert R&D inputs, including asset sale proceeds, into future growth and income is a central issue regarding R&D smoothing with financing asset sales. A firm's innovation outcomes are determined not only by its R&D inputs but also (and more importantly) by its innovation efficiency (Fu, 2012; Hottenrott and Peters, 2012).[3] As pointed out by Zhang(2015), R&D investment may threaten a firm's existence and development if a large proportion of the resources it devotes to innovation projects are unproductive. Thus, R&D-intensive firms are more likely to transfer asset sale proceeds to R&D investments if their innovation efficiencies are high. Innovation efficiency may therefore provide a compelling motivation for R&D smoothing through financing asset sales.

While many studies have investigated innovation activities, studies on R&D smoothing with financing asset sales have moved to the forefront of innovation management research (e.g., Brown and Petersen(2011; 2015); Borisova and Brown(2013)). However, the literature has not yet identified the determinants of financing asset sales for R&D smoothing. Specifically, how financial constraints and innovation efficiency affect the R&D smoothing with financing asset sales among R&D-intensive firms has not been fully explored.

This study attempts to shed light on these issues by providing empirical evidence from R&D-intensive firms listed on China's stock markets. This paper differs from previous studies in that it examines the determinants of converting asset sale proceeds to R&D investment and the impacts of innovative capabilities on investment

[3] Similarly, Lach and Schankerman (1989) and Kang et al. (2017)find that R&D activity is determined jointly by economic factors and technological capability.

adjustment and financing decisions. Specifically, this study contributes to the literature as follows. First, this appears to be the first study, to the best of our knowledge, to consider the interaction effect of financial constraints and innovation efficiency in R&D-asset sale sensitivity comprehensively. Second, we consider both operating assets sale and financial assets sale and compare their impacts on R&D protection, since these two types of asset sales have different financing costs due to asset specificity. Finally, we consider different levels of technological innovation capabilities and examine the heterogeneous moderating effects of innovation efficiency on R&D-asset sale sensitivity. Our study connects asset divesture theories to R&D investment management from the perspective of R&D smoothing with asset sales, and helps understand the investment adjustment and financing decision behavior of R&D-intensive firms in emerging markets like China.

Our exploration of R&D smoothing with financing asset sales produces four major findings. First, we reveal that R&D-intensive firms have incentives to protect their R&D investments by selling operating and financial assets. Second, we find that financial constraints, in sharp contrast to innovation efficiency, have negative moderating effects on the relationship between asset sales and R&D investments. Third, the results show that financially constrained firms with high innovation efficiency are more inclined to protect their R&D investments with financing asset sales. Finally, the study reveals that innovation efficiency plays a dominant role in R&D smoothing with financing asset sales, while financial constraints may serve as an alternative motivation for asset sales.

The rest of this paper proceeds as follows. Section 2 reviews the relevant literature. Section 3 discusses the study’s theoretical framework and presents the hypotheses. Section 4 explains the study’s methodology. Section 5 presents the data, indices, and empirical results. Section 6 conducts a robustness test. Finally, Section 7 concludes the paper.

2. Literature review on R&D financing

It is commonly argued that R&D-intensive firms have strong incentives to maintain a smooth path of R&D investment owing to the multiple types of adjustment costs involved (Borisova and Brown, 2013; Brown and Petersen, 2015; Kang et al., 2017). First, R&D investments are accompanied by substantial expenses for firing or rehiring highly-trained scientists, engineers and other specialists, who often require a large amount of firm-specific training (Lach and Schankerman, 1989; Himmelberg and Petersen, 1994; Hall, 2002; Peter and Taylor, 2017). The valuable firm-specific knowledge embedded in human capital is also lost when employees are released. Moreover, critical proprietary information will likely be disseminated to competitors, undermining innovation value. Second, R&D investment is associated with high sunk costs, as it is largely unrecoverable (Máñez et al., 2009). These costs usually constitute entry and exit barriers for innovation activities (Ganter and Hecker, 2013; Kang et al., 2017). Third, innovation project termination may demoralize team members and raise concerns about job security (Balachandra et al., 1996). Finally, R&D investment suffers from time-compression diseconomies (Dierickx and Cool, 1989; Sears, 2017; 2018). In other words, it is more efficient for R&D investment to keep consistency over a long period rather than double the total investment over a half-time interval.

Although firms try to smooth R&D investment, it is difficult to obtain externally (especially debt) financing for R&D-driven innovation (Hall, 2002). External financiers such as equity investors and banks are reluctant to invest in R&D projects because of their unique characteristics. First, R&D investments generally involve high risk and uncertainty regarding their final output and economic return (Hall, 2002; Hall and Lerner, 2010; Fernandez, 2017). As pointed out by Ghosal and Ye (2015) and Banerjee and Siebert(2017), various kinds of uncertainties, such as technological, demand (Pindyck 1993a, 1993b), and policy uncertainties (Wang et al., 2017), arise throughout different stages of the R&D process. These uncertainties impede external financing for such projects, as they frequently result in development failures (Banerjee and Siebert, 2017).

Second, most R&D investments are intangible assets, which are highly irreversible and offer very limited collateral value (Almeida and Campello, 2007; Drivera and Guedes, 2012). A lesser ability to pledge collateral increases the cost of external financing and reduces debt capacity (Benmelech and Bergman, 2009), while higher-risk firms are generally required to pledge collateral for bank loans (Berger and Udell, 1990). As noted by Hall (2002), banks and other debt-holders prefer to lend when the project involves tangible (physical) assets rather than R&D investments. Nevertheless, servicing debt usually demands a steady cash flow, which in turn diminishes the cash flow available for future investments (Hall, 2002; Hottenrott and

Peters, 2012). The cash flow requirement makes external fundraising difficult and unappealing, as most R&D projects are not immediately productive.

Finally, R&D investment projects are likely to suffer from information asymmetry problems. Innovators generally have information about the probability of technical success and the profitability of their current innovation projects that is superior to the information possessed by potential investors (Hall and Lerner, 2010; Drivera and Guedes, 2012). Firms have incentives to keep secrecy regarding the details of R&D projects to avoid disseminating valuable information to competitors (Mohamed and Schwienbacher, 2016), though it raises their cost of capital because of the lemons premium (Hall, 2002; Balakrishnan et al., 2014).[4] Meanwhile, information asymmetries are also exacerbated by accounting rules, the absence of organized innovation markets, and the uniqueness of R&D investments (Aboody and Lev, 2000; Guariglia and Liu, 2014).

Given these financial constraints, R&D-intensive firms may use their internal cash flow or cash holdings for R&D smoothing (Brown and Petersen, 2011; He and Wintoki, 2016; Ahrends et al., 2018; Shao and Xiao, 2019),[5] as external financing is either unavailable or more expensive than internal financing (Bernini and Montagnoli, 2017). However, internal cash holdings are exhaustible, and cash flow is naturally restricted (Hottenrott and Peters, 2012). In this scenario, firms may be forced to sell non-core assets and utilize the proceeds to maintain their R&D investments (Borisova and Brown, 2013; Brown and Petersen, 2015). Asset sales provide an alternative way to raise capital in order to finance investment opportunities or meet liquidity needs (Edmans and Mann, 2019) when external financing is scarce or costly (Borisova et al., 2013).

According to Borisova and Brown(2013), the average asset sale increases R&D intensity by 6.9% of the sample mean, which is only slightly less than the amount that would be generated (8.8%) by stock issues. Meanwhile, Hovakimian and Titman (2006) find that the sensitivity of investments to asset sale proceeds is significantly stronger for financially constrained firms. Furthermore, Brown and Petersen (2015)

[4] Admittedly, the relationship between a firm's capital cost and disclosure quality may depend on growth rate thresholds (Dutta and Nezlobin, 2017).

[5] However, the financing sources for R&D investment remain ambiguous. Some researchers, such as Brown et al.(2012), find that external equity financing plays a major role for R&D investments. Contrariwise, Chay et al. (2015)find that firms use internal funds for R&D investments. Similarly, Sasidharan et al. (2015)fail to find any significant evidence that firms use external equity for R&D financing or engage in R&D smoothing using cash reserves.

find that financially constrained firms favorably allocate cash holdings to buffer R&D investments, even taking the extreme step of allowing their fixed investments to fall.

Although previous studies provide valuable insight into R&D smoothing, most studies seek to identify financial constraints by controlling for R&D smoothing (e.g., Hovakimian and Titman(2006); Brown et al.(2012); Hottenrott and Peters(2012); He and Wintoki(2016)) rather than the issue *per se*. Only a few recent studies, such as Brown and Petersen(2011), Borisova and Brown(2013), and Brown and Petersen(2015), have discussed R&D smoothing with cash holdings or asset sale proceeds. More recently, Kang et al.(2017) have examined the impact of technological capability on the persistence and volatility of R&D investment. However, these studies have neither addressed the determinants of R&D smoothing with financing asset sales nor examined their impacts on the relationship between asset sales and R&D investment protection. This study attempts to fill these gaps by examining the heterogeneous effects of financial constraints and innovation efficiency on R&D smoothing with financing asset sales.

3. Theory and hypotheses

The literature review shows that R&D smoothing is of significant importance for R&D-intensive firms owing to various adjustment costs, including firing or rehiring costs for highly skilled employees, sunk costs, and time-compression diseconomies (Borisova and Brown, 2013; Brown and Petersen, 2015; Kang et al., 2017). However, it is difficult for these firms to smooth their R&D investments, since R&D activities are easily subject to financial constraints due to high uncertainty, asymmetric information, and limited collateral value (David et al., 2000; Hall, 2002; Brown et al., 2012). Facing financial constraints, these firms may choose to protect some value-enhancing investments according to capital adjustment costs while cutting their investment expenditures. For example, Borisova and Brown (2013) show that firms with limited external financing use the funds obtained from tangible assets sale for R&D activities. Similarly, Brown and Petersen (2015) also point out that fixed asset investment is reduced more than R&D investment when firms face severe financial shocks in the financial crisis. Therefore, firms are inclined to allocate more cash flow into intangible assets (e.g. R&D investment) rather than into tangible assets when selling assets.

As far as asset sales are concerned, financial assets sale rather than operating assets sale plays an important role of financing in corporate financial decisions. Some studies begin to pay attention to the relationship between firm financial asset allocation and R&D innovation investment (Hahn, 2019). Compared to operating assets associated with high asset specificity, it is less costly for firms to raise funds by selling financial assets, since the latter generally trade at a lower liquidity cost in a more active trading market. Financial assets with high liquidity can be used as precautionary savings for R&D investment and alleviate the negative effects of financial constraints on R&D activities. In this regard, financial assets sale is beneficial to R&D investment. Apart from financing facility, however, the excess returns of arbitrage also provide firm a speculative motivation to allocate the proceeds from financial assets sale (Orhangazi, 2008; Demir, 2009). As pointed out by Orhangazi (2008) and Demir (2009), the allocation of financial assets has a "crowding out effect" on other types of investment. In other words, financial assets sale may have adverse impact on R&D investment.

As the particular impact of financial assets sale on R&D protection remains unclear, R&D-intensive firms in China provide a unique experiment for studying this issue. In recent years, many China's non-financial firms have been distracted from their main business and involved in financial and real estate fields. These firms allocate excessive investment in financial assets to obtain higher returns than their main business, so that the investment income of financial assets have gradually become an important part of profits (Zhang and Zhang 2016). Meanwhile, the proportion of corporate financial asset investment has also increased greatly, especially after 2012 when the China Securities Regulatory Commission issued the *Guidelines for the Supervision and Administration on Listed Companies No.2-Supervision and Administration Requirements for Listed Companies on the Management and Use of Raised Funds.* The guidelines allow listed firms to use idle raised funds to purchase investment products with high security and good liquidity. As a result, the average holdings of financial assets by non-financial listed firms have increased greatly in China, which is presented in Figure A.1 in Appendix.

Overall, operating assets sale and financial assets sale may have heterogeneous effects on R&D protection, since these two types of asset sales have different liquidity costs. For the comparison purpose, this study considers both operating assets and financial assets sales and proposes the general hypothesis as follows.

H1. *Research and development-intensive firms have incentives to protect their value-enhancing R&D investments by selling assets with relatively low adjustment costs, such as operating assets and financial assets.*

However, R&D-intensive firms may face a R&D protection dilemma when they are financially constrained. On the one hand, financially constrained firms may tend to protect their R&D investments by selling non-core assets, as this provides alternative funds when external financing is especially scarce or costly (Borisova and Brown, 2013). On the other hand, financially constrained firms may be forced to reduce their R&D investments, as they typically use the proceeds from asset sales to meet debt obligations (Shleifer and Vishny, 1992) rather than retain the sale proceeds within the firm (Lang et al., 1995). Therefore, the competing hypotheses below are proposed:

H2a. *Financially constrained firms are more inclined to protect their R&D investments with financing asset sales.*

H2b. *Financially constrained firms are forced to reduce their R&D investments when they raise capital through financing asset sales.*

Nevertheless, how to efficiently convert the proceeds from asset sales into innovation outputs is a fundamental issue for firms engaged in R&D smoothing through financing asset sales. The conversion process depends heavily on innovation efficiency, which directly determines the innovation outputs achieved from a given set of innovation inputs (Fu, 2012; Guan and Chen, 2012), as dedicating more innovation inputs cannot, alone, guarantee innovation outcomes(Zhang 2015). As pointed out by Cruz-Cázares et al.(2013), the key to increasing firm performance is technological innovation efficiency. Gao and Chou (2015) find that innovation efficiency can improve the value of multinational firms. Similarly, Hirshleifer et al. (2013)find that innovative efficiency contributes to operating performance and firm value. Firms with higher innovation efficiency are more likely to achieve innovation outputs, and thus have a strong incentive to protect their ongoing R&D projects. This leads to the final hypothesis:

H3. *Research and development-intensive firms with higher innovation efficiency are more likely to sell assets to protect their R&D investments.*

4. Methodology

4.1 Baseline model of R&D smoothing

Inspired by the seminal work of Brown et al. (2009)and Brown and Petersen(2011), this study constructs dynamic R&D models with financial variables to examine the R&D smoothing with financing asset sales. These models are based on an Euler equation proposed by Bond and Meghir (1994) under the assumption of quadratic adjustment costs for productive assets. The Euler equation is a structural model created through derivation from the dynamic optimization "Euler condition" for imperfect competition. It captures the impact of current expectations of future profitability on current decisions (Bond et al., 2003; Brown et al., 2009; Whited and Wu, 2006).

Incorporating asset sale proceeds (ASale) for R&D smoothing, the Euler equation leads to the following empirical specification:

$$Rd_{i,t} = \alpha_1 ASale_{i,t} + \alpha_2 IE_{i,t-1} + \alpha_3 FC_{i,t-1} + \alpha_4 Rd_{i,t-1} + \alpha_5 Rd^2_{i,t-1} + \alpha_6 Growth_{i,t} + \alpha_7 Cf_{i.t} + \alpha_8 Debt_{i,t} + \alpha_9 Stk_{i,t} + \alpha_{10} Size_{i,t} + \mu_i + v_t + \varepsilon_{i,t} \quad (1)$$

$$ASale = OP, or\ Inv$$

where $Rd_{i,t-1}$ reflects the R&D spending of firm i at period $t-1$, while $Rd^2_{i,t-1}$ denotes the quadratic adjustment costs of R&D investment. $ASale$ represents the proceed from each type of assets sales, namely, operating assets sale (OP) or financial assets sale (Inv). Innovation efficiency (IE) and financial constraint (FC) are two main explanatory variables. Following Borisova and Brown (2013), this study also considers financial variables at the firm level, such as cash flow (Cf), net debt issues ($Debt$), and net stock issues (Stk). Meanwhile, investment opportunities ($Growth$) and firm size ($Size$) are also included to control for investment demand. Eq. (1) also incorporates firm-fixed effect (μ_i) and time-specific effect (v_t) to control for unobserved, time-invariant factors, and aggregate changes respectively. Finally, $\varepsilon_{i,t}$ is the idiosyncratic error term. The constant terms in the regression models are omitted for the sake of brevity. All financial variables are scaled by total assets at the beginning of the period. A detailed explanation of these variables is provided in Table A.1 in Appendix.

The parameters in Equation (1) can be interpreted as functions of those in the original optimization problem of the Euler equations (Brown et al., 2009; Guariglia and Liu, 2014). Under the assumption of quadratic adjustment costs in the Euler condition, the expected coefficient on lagged R&D should be positive and that on the quadratic term should be negative. As aforementioned, the coefficients on OP and Inv should be positive for firms that choose to protect their R&D investments by selling assets.

Meanwhile, the coefficients of $Debt$ and FC are predicted to be negative.[6] Firms with high debt ratios are more likely to reduce their R&D expenditures because R&D investments may evaporate in times of financial distress (Bhagat and Welch, 1995). Moreover, cash flow (Cf) and stock issues (Stk) should share a positive relation with R&D, while a similar pattern is expected to emerge in the relationships between R&D and investment opportunities ($Growth$), firm size ($Size$), and innovation efficiency (IE).

4.2 Moderating effect of financial constraints

Since the seminal work of Fazzari et al.(1988), a large body of literature has focused on the identification of financial constraints (e.g., Brown et al.(2012); Chen and Chen(2012); Foley-Fisher el al.(2016); Moshirian et al.(2017)). However, there is no consensus on how to measure financial constraints properly, and a diverse range of approaches has been applied (Erel et al., 2015; Chen et al., 2017). The main measures include the Kaplan–Zingales (KZ) index (Kaplan and Zingales, 1997), the Whited–Wu (WW) index (Whited and Wu, 2006), and the investment-cash flow sensitivity (ICFS) method (Fazzari et al., 1988).[7] As pointed out by Erel et al.(2015), each measure has limitations while also providing valuable insight into how to assess financial constraints.

As an alternative, the Euler equation approach is proposed by Howell(2016). This approach, based on the Euler equation, has several advantages over the other measures(Howell 2016). First, this approach addresses the critique of Kaplan and Zingales (1997) that ICFS is not a reliable measure of financial constraints, as their claim has not been substantiated in the dynamic multiperiod setting of the Euler equation. Second, this approach requires no further information regarding firms'

[6] The literature does not provide a clear determination of the relationship between R&D investment and debt. Some studies, such as Bhagat and Welch (1995) and Wang(2017), find that R&D investments are negatively associated with indebtedness. By contrast, Guney et al. (2017)argue that firms may use credit lines to finance their R&D investments. Mann (2018) finds that patenting companies conduct significant debt financing for innovation.
[7] The readers are referred to Khatami et al. (2015)and Mulier et al. (2016)for excellent literature reviews on financial constraints.

market value or dividends, and the assumptions required to estimate the Euler equation are less restrictive. Finally, this approach controls for all expectations of future influences on current investment decisions.

Incorporating a set of firm characteristics to represent financial constraints, the Euler equation is specified as follows:

$$I_{i,t} = \mu_1 I_{i,t-1} + \mu_2 Sales_{i,t-1} + \Omega * Cf_{i,t-1} + \eta_t + \xi_{i,t} \quad (2)$$

with

$$\Omega = v_1 Size_{i,t} + v_2 Age_{i,t} + v_3 Lev_{i,t} + v_4 cash_{i,t} \quad (3)$$

where $I_{i,t}$ is the investment expenditure of firm i in period t, $Sales_{i,t-1}$ the net revenue generated from the selling of products, goods and services in the previous year, $Cf_{i,t-1}$the net cash flow received from operating activities in the previous period, $Size_{i,t}$ the firm size measured by the firm's total assets, $Age_{i,t}$firm age, $Lev_{i,t}$ the ratio of long-term liabilities to total assets, and $cash_{i,t}$ the cash holding.

Firm size, age, cash flow, and leverage are generally believed to capture a firm's financial constraints well (e.g., Rauh(2006); Hadlock and Pierce(2010); Mulier et al. (2016)and Howell(2016)). Firm size and age are the most important factors in any measure of financial constraints (Beck et al., 2006; Fee et al., 2009; Hadlock and Pierce, 2010). A firm's age is closely associated with its informational opacity, which affects its creditworthiness and capital costs due to information asymmetry and adverse selection (Hyytinen and Pajarinen, 2008). Firm size also matters for credit extension, which involves overcoming problems of information asymmetry and insufficient collateral (Bernanke et al., 1996). Smaller firms tend to face more severe financial constraints because they are more likely to have volatile growth patterns and earnings (Howell 2016) and less of a proven track record(Schiantarelli 1996). Meanwhile, cash flow is crucial for repaying debt and therefore determines the firm's debt capacity (Mulier et al., 2016). Finally, less-levered firms are more likely to be financially unconstrained because they are stable and profitable (Strebulaev and Yang, 2013), and thus have lower solvency risk (Mulier et al., 2016).[8] Unlike Howell(2016), this study does not include other variables, such as export and subsidy variables,

[8] Admittedly, there is a controversy regarding the relationship between financial constraints and indebtedness. As pointed out by Bessler et al.(2013), for example, most zero-leverage (i.e., extreme debt-conservative) firms are financially constrained because they have insufficient debt capacity, while only a small number of financially unconstrained firms with high profitability and dividend payment may deliberately choose a zero-leverage policy by avoiding debt financing. Readers are referred to Bessler et al. (2013)and Dang(2013) for detailed literature reviews.

owing to data unavailability issues.

The estimated coefficients for the $\upsilon's$ in Equation (3) are used to calculate the firm-specific financial constraint score, which is based on the firm's characteristics. Although the estimated coefficients remain constant over the full sample period, the degree of a firm's financial constraints is time-varying because its features change over time. The firm-level financial constraint score Fi,t is obtained as follows:

$$F_{i,t} = v_1 Size_{i,t} + v_2 Age_{i,t} + v_3 Lev_{i,t} + v_4 cash_{i,t} \quad (4)$$

A firm is considered to be financially constrained if $F_{i,t} > 0$, while a higher score indicates more severe financial constraints. For ease of interpretation, a dummy variable FC is set equal to one if $F_{i,t} > 0$ and zero otherwise. In other words, firms are sorted into financially constrained and unconstrained groups according to their financial constraint scores.

The dummy variable FC is introduced to examine the moderating effect of financial constraints on the relationship between asset sales and R&D protection. Incorporating the interaction term of financial constraint and proceeds from asset sales, Equation (1) is reformulated as follows:

$$Rd_{i,t} = \gamma_1 ASale_{i,t} + \gamma_2 Asale_{i,t} \times FC_{i,t-1} + \gamma_3 FC_{i,t-1} + \gamma_4 IE_{i,t-1} + \gamma_5 Rd_{i,t-1} + \gamma_6 Rd^2_{i,t-1} + \gamma_7 Growth_{i,t} + \gamma_8 Cf_{i.t} + \gamma_9 Debt_{i,t} + \gamma_{10} Stk_{i,t} + \gamma_{11} Size_{i,t} + \mu_i + v_t + \varepsilon_{i,t} \quad (5)$$

$$ASale = OP, or\ Inv$$

where coefficient γ_2 represents the magnitude of the moderating effect of financial constraints on financing asset sales (operating assets or financial assets). A positive coefficient γ_2 represents that financially constrained firms protect their R&D investments with the proceeds from asset sales; otherwise, the firms reduce their R&D investments when raising capital through asset sales.

4.3 Moderating effect of innovation efficiency

A firm's innovation efficiency is generally understood as its capacity to generate innovation outputs per unit of innovation inputs (Li, 2009; Hirshleifer et al., 2013; Gao and Chou, 2015; Knut et al., 2017). Numerous studies have adopted a wide range of indicators for innovation inputs, such as innovation expenditure (Fu, 2012; Knut et al., 2017), R&D capital (Hirshleifer et al., 2013; Griffin et al., 2018), and R&D manpower (Wang and Huang, 2007; Fu, 2012). Some studies have also proposed a variety of innovation output indicators, including patents and patent citations (Seru, 2014; Gao and Chou, 2015), innovative sales(Fu 2012), and product innovation (Cruz-Cázares et al., 2013). Unfortunately, there is no widely accepted measurement, as the mixed use of different types of indicators may lead to ambiguous results (Cruz-Cázares et al., 2013).

Following Hirshleifer et al. (2013)and Griffin et al.(2018), this study uses the share of a firm's number of patent filings scaled by its R&D expenditures as the measure of innovation efficiency. This measure indicates the firm's capability to transform innovation input (i.e., R&D expenditures) into innovative output (i.e., patents).[9] Although patent citations provide valuable information regarding the quality of innovative output (Gao and Chou, 2015), this study does not include these data, as they are unavailable in China.

Instead, this study considers three types of patents in China, namely, invention, utility model, and design. These three types of patents reflect the technological and economic significance of patents as they help distinguish between breakthrough innovations and less-innovative or superficial novelties.[10] To provide the broadest coverage, this study constructs three indicators of innovation efficiency using the shares of the firm's patent application filings for inventions, utility models, and designs divided by its R&D expenditures respectively. These indicators of innovation efficiency, denoted by IE', IE'', and IE''' correspondingly, capture innovation qualities well. It is worth noting that this study mainly focuses on inventions and utility models, as they both involve "new technical solutions", which is not involved in designs.[11]

The innovation efficiency indicator IE (IE', $IE''$and IE''') is included to examine the moderating effect of innovation efficiency on the relationship between asset sales and R&D protection. Incorporating the interaction term of innovation efficiency and proceeds from asset sales, Equation (1) is reformulated as follows:

$$Rd_{i,t} = \delta_1 ASale_{i,t} + \delta_2 Asale_{i,t} \times IE_{i,t-1} + \delta_3 IE_{i,t-1} + \delta_4 FC_{i,t-1} + \delta_5 Rd_{i,t-1} + \delta_6 Rd^2_{i,t-1} +$$

[9] Although patents, like other indicators, are subject to criticism, they are one of the most readily available and reliable measures of innovation output (Li, 2009; Gao and Chou, 2015).

[10] According to China's patent system, patent quality varies across three categories (Li, 2009). Invention patents represent the most valuable and technologically sophisticated innovation outputs. Utility models are less significant than inventions in terms of technological innovation but are more innovative than designs. In other words, designs contain less technological innovation and indicate superficial novelty. China's "invention patents" are equivalent to US "utility patents", while "design patents" in China are similar to their US counterparts. However, China's "utility models" have no US equivalent (Christodoulou et al., 2018). Readers are referred to *the Patent Law of the People's Republic of China* for definitions of inventions, utility models, and designs.

[11] Invention patents in China are relatively sparse compared to utility model and designs patents.

$$\delta_7 Growth_{i,t} + \delta_8 Cf_{i.t} + \delta_9 Debt_{i,t} + \delta_{10} Stk_{i,t} + \delta_{11} Size_{i,t} + \mu_i + v_t + \varepsilon_{i,t} \quad (6)$$

$$ASale = OP, or\ Inv, and\ IE = IE', IE'' or\ IE'''$$

where coefficient δ_2 represents the magnitude of the moderating effect of innovation efficiency on asset sales, and $\varepsilon_{i,t}$ is the residual. The coefficient δ_2 is expected to be positive if firms with high innovation efficiency are more likely to protect their R&D investments by financing asset sales.

This study examines the combined impact of financial constraints and innovation efficiency by incorporating the interaction term of financial constraint and proceeds from asset sales and a triple interaction term of innovation efficiency, financial constraints, and asset sale proceeds into Equation (6) and reformulates it as follows:

$$Rd_{i,t} = \tau_1 ASale_{i,t} + \tau_2 Asale_{i,t} \times FC_{i.t-1} \times IE_{i,t-1} + \tau_3 Asale_{i,t} \times FC_{i.t-1} + \tau_4 Asale_{i,t} \times IE_{i,t-1} + \tau_5 FC_{i.t-1} + \tau_6 IE_{i,t-1} + \tau_7 Rd_{i,t-1} + \tau_8 Rd^2_{i,t-1} + \tau_9 Growth_{i,t} + \tau_{10} Cf_{i.t} + \tau_{11} Debt_{i,t} + \tau_{12} Stk_{i,t} + \tau_{13} Size_{i,t} + \mu_i + v_t + \varepsilon_{i,t} \quad (7)$$

$$ASale = OP, or\ Inv, and\ IE = IE', IE'' or\ IE'''$$

where coefficient τ_2 represents the extent to which financial constraints and innovation efficiency jointly impact the moderation between asset sales and R&D investment. The coefficient τ_2 is predicted to be positive if financially constrained firms with high innovation efficiency sell assets to protect their R&D investments.

5. Empirical analysis

5.1 Indices and data description

This study selects Chinese A-share listed companies with significant R&D investments from 2009 to 2016 to examine their R&D smoothing with financing asset sales.[12] These companies are listed on Chinese exchanges and primarily available for domestic investors. Most of these firms are in technology-intensive industrial sectors, including the chemical material industry, pharmaceutical industry, general equipment industry, specialized equipment industry, automotive industry, computer industry, and software and information technology services industry.[13] In order to select firms with

[12] The Chinese government implemented the *New Accounting Standards* in 2007 to regulate information disclosure with respect to investment accounts. This study does not include the data before 2009 to avoid the distortions caused by accounting standards changes and the global financial crisis in 2008.

[13] According to the *Statistics Catalogue of High-technology Industry Classifications* issued by the National Bureau of Statistics of China in 2002, China's technology-intensive industrial sectors are concentrated in electronics and communications equipment manufacturing, electronic computer and office equipment

substantial R&D expenditure, this study excludes any firm without at least four positive R&D observations in the sample period (i.e., 50% during the period).[14] In so doing, there are at least five listed companies within each sector. In addition, this paper also eliminates the ST and *ST firms. A total of 2142 observations remain to be analyzed after preliminary screening. These datasets meet the sample requirement as all firm-level datasets should be standardized by the mean and standard deviation of their industries.

Firms' financial data are retrieved from the Wind Financial Database, which the literature has often used (e.g., Zheng et al.(2018); Jiang and Yuan(2018)), while patent information is collected from the official website of the State Intellectual Property Office of China (SIPOC). Operating assets sale is calculated according to the cash received from the sale of fixed assets, intangible assets and other long-term assets, while financial assets sale is the cash received from the investment recovery in the cash flow statement of the firm.[15] All continuous variables are winsorized at the 1st and 99th percentiles to mitigate the impact of possible outliers. The detailed information on the variables is presented in Table A.1 in Appendix, and summary descriptive statistics for the firms' financial data are displayed in Table 1.

Table 1. Descriptive statistics for financial variables

	Full sample (N = 2142)		Financially unconstrained (N = 388)		Financially constrained (N = 1754)		Mean difference between two groups	
Variable	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	t-statistic	Z-statistic
$Rd_{i,t}$	0.0279	0.0238	0.0223	0.0197	0.0291	0.0249	-0.4884	0.033
$OP_{i,t}$	0.0028	0.0107	0.0004	0.0010	0.0033	0.0141	-1.5081*	-3.196**
$Inv_{i,t}$	0.0554	0.3594	0.0415	0.1392	0.0801	0.3511	-0.7993*	-2.487*
$Cf_{i,t}$	0.0393	0.0605	0.0412	0.0687	0.0407	0.0602	-1.0292	-1.5013
$Growth_{i,t}$	0.3094	3.2748	0.2569	0.1472	0.4004	3.9077	-0.1797	4.003***
$Stk_{i,t}$	0.0968	0.2806	0.0436	0.1739	0.1234	0.2682	-2.0850**	-2.632**
$Debt_{i,t}$	0.0429	0.0983	0.0412	0.0927	0.0509	0.1012	-0.0994*	-1.010*
$Size_{i,t}$	21.8869	1.1704	22.0122	1.2003	20.9353	0.9987	-1.0273*	-2.501*
$Lev_{i,t}$	0.3072	0.2001	0.2002	0.1731	0.3790	0.1934	-8.0211***	-8.9750***
$IE_{i,t-1}$	0.4022	0.9980	0.3410	0.4879	0.3994	0.8011	-0.1610	0.0328

manufacturing, pharmaceutical manufacturing, and medical equipment manufacturing.

[14] The results in general are robust and consistent under more restrictive conditions.

[15] According to CASs, cash received from investment recovery refers to the cash received by the company from the sale, transfer or maturity of transactional assets (other than cash equivalents), held-to-maturity investments, available-for-sale financial assets, long-term equity investments, and investment real estate.

Notes: In this table, N stands for the number of observations. The mean differences between financially constrained and unconstrained groups are obtained using the t-test and the Wilcoxon (Mann–Whitney) rank-sum test respectively. ***, **, and * denote significance at the 1%, 5%, and 10% levels respectively. Definitions of variables are provided in Table A.1 in Appendix.

As shown in Table 1, the average R&D intensity (Rd) is 2.79%, while the mean of the operating assets sales ratio (OP) is 0.28% and that of financial assets sales (Inv) is 5.54%. Financial assets sales are more salient in Chinese R&D-intensive firms than operating assets sales and are nearly double R&D intensity. In other words, not all proceeds from asset sales are put into R&D investment. Firms with financial assets sales may have certain motivation for speculative profits. For example, the average holdings of financial assets by Chinese non-financial listed firms have increased significantly according to the secular trend of financial asset allocation presented in Figure A.1 in Appendix. The share of cash flow from operating activities (Cf) is 3.93%, which is almost equivalent to that of debt issues (4.29%) and is half that of stock issues (9.68%). Nevertheless, asset sales play an important role in raising funds, accounting for nearly 32.5% of total fundraising

Table 1 also shows that most R&D-intensive firms in China are financially constrained, even though they are listed firms on Chinese stock markets. This result is consistent with the results of previous studies regarding the characteristics of R&D investments. The mean differences between financially constrained and unconstrained groups show that these two groups are statistically significant with respect to net stock issues (Stk), and leverage (Lev). Financially constrained firms generally have greater leverage, and stock issues. However, there is no significant difference between the two groups in terms of other firm features, such as cash flow (Cf), innovation efficiency (IE), and R&D investment (Rd). These findings somewhat alleviate the endogeneity concern regarding firm performance, innovation efficiency, and R&D investment because, intuitively, they affect each other. Moreover, the two groups are barely significant in terms of firm size ($Size$) and net debt issues ($Debt$).

5.2 Generalized method of moments estimation results

Dynamic panel data models may suffer from endogeneity, though some variables are uncorrelated. This study employs the system generalized method of moments (GMM) estimator developed by Arellano and Bover (1995) and Richard and Bond (1998) to address the potential endogeneity of the regression variables.[16] The system-GMM

[16] The GMM model can also address temporal specific and individual effects (Bandyopadhyay and Barua, 2016)

estimator regards all variables, including differenced and lagged variables, as potentially valid instruments if they are uncorrelated with the error term (Guney et al., 2017). The GMM model controls for endogeneity via data transformation (Ullah et al., 2018), which includes first-difference transformation (one-step GMM) and second-order transformation (two-step GMM). To avoid potential data loss associated with the one-step GMM (Ullah et al., 2018), this study uses the two-step GMM method to estimates the regressions with lagged dependent variables up to period $t-4$ as instruments.[17] The downward-biased standard errors of the two-step GMM for small samples are also calibrated via Windmeijer's (2005) finite-sample correction. The two-step GMM estimators are reported in Tables 2 and 3 respectively.

This study also uses the Sargan test of over-identifying restrictions to assess instrument validity and the Arellano–Bond test to examine autocorrelation in residuals (Ullah et al., 2018). According to the Sargan test, the instruments included in the econometric models are exogenous if the test turns out to be statistically insignificant. For the Arellano–Bond test, the GMM estimator is valid if a first-order serial correlation (i.e., m1) is observed and there is no second-order serial correlation (i.e., m2) in the residuals. The results of the Sargan and Arellano–Bond tests are reported in Tables 2 and 3 respectively. The results show that the GMM estimators in this study pass the diagnostic tests and are therefore valid.

5.3 R&D protection via asset sales

This section uses the two-step GMM to estimate the regressions and analyzes the impacts of financial constraints and innovation efficiency on R&D protection by asset sales. Tables 2 and 3 report the GMM estimators with respect to R&D protection with proceeds from operating assets sale and financial assets sale respectively.

As shown in Tables 2 and 3, the coefficients on lagged R&D are significantly positive at the 1% level, while those on their quadratic terms are significantly negative. This finding is consistent with the expectation that there are quadratic adjustment costs in R&D investment. Meanwhile, the coefficients associated with innovation efficiency (IE), investment opportunities ($Growth$), and cash flow (Cf) are significantly positive, while that of net debt issues ($Debt$) and financially constraint (FC) are significantly

as well as the dynamic panel bias arising from the correlation between firm-specific fixed effects and lagged dependent variables (Guney et al., 2017).

[17] This study also tried the one-step GMM and found that the model could hardly pass the over-identification test.

negative. These findings imply that R&D investment is determined not only by firms' financial conditions but also by their previous R&D investments, innovation efficiency, and market conditions.

More interestingly, R&D protections with operating assets sales and financial assets sales are generally salient after controlling for other financial variables. The coefficients associated with asset sale proceeds from operating assets (OP) and from financial assets (Inv) in Eq. (1) are significantly positive at the 1% level, except the coefficient of Inv for design case, which is only significant at the 10% level. These results support Hypothesis 1 that firms are generally inclined to protect their R&D investments by selling their operating assets and financial assets. The results also support previous studies suggesting that R&D-intensive firms tend to use available internal financing, rather than external financing, for their R&D investments.

Tables 2 and 3 also show that the coefficients on the interaction terms of financial constraints and operating assets sales are significantly negative for both invention and utility model in Eq. (5) (at level of 1% and 10% respectively). However, their counterparts are negative but insignificant at conventional levels in the design case. These findings reject Hypothesis 2a and therefore support Hypothesis 2b, implying that financial constraints have a negative moderating effect on R&D protection with financing asset sales, especially for firms with cutting-edge innovation. These firms may face more uncertainty and higher risk of R&D failure, and therefore, the negative effects of financial constraints are more prominent (Kamien and Schwartz, 1978). This finding is consistent with Campello et al. (2010) and Zhang (2015) that financially constrained firms are more likely to reduce, rather than protect, their R&D investments, even if they choose to raise capital by selling assets. This finding also supports the view of Borisova and Brown (2013) that the R&D financing consideration is not the primary motivation for asset divestitures.

Tables 2 and 3 further show that most of the coefficients on the interaction terms of IE and OP (or Inv) are statistically significant for the three innovation types. The positive coefficients in Table 2 suggest that innovation efficiency has significantly positive moderating effects on R&D protection by operating assets sales, supporting Hypothesis 3. By contrast, the coefficients on the interaction terms of innovation efficiency and financial assets sale in Table 3 are significantly positive for the cases of innovative patents (invention and utility model), while the one in the case of superficial novelty (design) is insignificant. This finding suggests that only firms with high innovation efficiency in core patents are inclined to protect their R&D investments with financial assets sale, partially supporting Hypothesis 3. This finding implies that firms with high efficiency in superficial innovation have less incentive to protect their R&D investments by selling financial assets, even though the financing cost of financial assets sale is lower than that of operating assets sale. The comparison results between two types of asset sales show that R&D smoothing with asset sales is partially influenced by innovation types.

The coefficients on the triple interaction terms in Tables 2 and 3 reflect the joint impact of financial constraints and innovation efficiency on R&D protection with asset sale proceeds. Tables 2 shows that the coefficients are significantly positive at the 1% level in the three innovation cases. Similarly, the coefficients on the triple interaction terms in Table 3 are significantly positive at the 1% level for invention and utility cases, while the coefficient for design case is insignificant. These findings suggest that financially constrained firms with high innovation efficiency are generally inclined to increase their R&D investment with proceeds from asset sales. In other words, innovation efficiencies in these scenarios (except the design case with financial assets sale) are large enough to offset the adverse impacts of financial constraints on R&D protection, so that financially constrained firms with innovative patents are willing to protect their R&D investments with asset sales.

In general, both operating assets sales and financial assets sales have positive impacts on R&D investment. However, R&D protection with operating assets sale is more salient than the one with financial assets sale. As shown by Tables 2 and 3, for example, the coefficients on operating assets sale and its interaction terms are more significant and larger than those coefficients on financial assets sale. This finding suggest that operating assets sale is mainly to raise funds for R&D protection while financial assets sale has some arbitrage motivations, other than financing facility, to be satisfied (Orhangazi, 2008; Demir, 2009). R&D financing consideration is probably a primary motivation for operating assets sale rather than financial assets sale. Given that operating assets sale has a relatively higher liquidity cost due to asset specificity, these findings also indicate that only truly innovative firms would like to adopt the R&D smoothing strategy with operating assets sales at higher financing costs.

Table 2. Financial constraints vs. innovation efficiency on R&D protection with proceeds from operating assets sales

	Invention ($IE = IE'$)				Utility model ($IE = IE''$)				Design ($IE = IE'''$)			
Variable	Eq. (1）	Eq. (5)	Eq. (6)	Eq. (7)	Eq. (1)	Eq. (5)	Eq. (6)	Eq. (7)	Eq. (1)	Eq. (5)	Eq. (6)	Eq. (7)
$Rd_{i,t-1}$	0.576***	0.488***	0.492***	0.531***	0.511***	0.492***	0.479***	0.519***	0.417***	0.423***	0.486***	0.505***
	(92.18)	(101.10)	(93.74)	(107.22)	(112.70)	(86.17)	(94.12)	(80.12)	(121.16)	(106.23)	(103.12)	(72.13)
$Rd^2_{i,t-1}$	-0.047***	-0.038***	-0.033***	-0.049***	-0.042***	-0.050***	-0.044***	-0.039***	-0.043***	-0.040***	-0.035***	-0.042***
	(-20.19)	(-13.14)	(-20.44)	(-17.52)	(-21.13)	(-16.00)	(-19.27)	(-17.33)	(-15.09)	(-16.62)	(-19.92)	(-15.78)
$OP_{i,t}$	0.033***	0.018**	0.315***	0.043	0.047***	0.055*	0.083**	0.244	0.041***	0.318**	0.072	0.015*
	(12.26)	(2.39)	(7.76)	(0.88)	(8.65)	(1.26)	(4.45)	(0.69)	(9.17)	(2.79)	(0.33)	(1.29)
$OP_{i,t} \times FC_{i,t-1}$		-0.310***		-0.008**		-0.030*		-0.015***		-0.045		-0.316
		(-5.32)		(-3.54)		(-1.22)		(-6.00)		(-1.31)		(-0.33)
$OP_{i,t} \times IE_{i,t-1}$			0.118***				0.553***				0.006***	
			(7.74)				(14.22)				(8.10)	
$OP_{i,t} \times FC_{i,t-1} \times IE_{i,t-1}$				0.313***				0.090***				0.111**
				(6.31)				(8.41)				(3.35)
$FC_{i,t-1}$	-0.116***	-0.052***	-0.108***	-0.088***	-0.100***	-0.089***	-0.104***	-0.077***	-0.075***	-0.080***	-0.058***	-0.041***
	(-12.35)	(-17.01)	(-13.34)	(-15.16)	(-17.31)	(-12.90)	(-15.77)	(-14.46)	(-16.29)	(-12.72)	(-10.35)	(-13.05)
$IE_{i,t-1}$	0.401***	0.348***	0.329***	0.288***	0.316***	0.272***	0.209***	0.278***	0.323***	0.300***	0.255***	0.302***
	(17.12)	(20.13)	(20.53)	(19.80)	(18.42)	(14.25)	(15.11)	(18.40)	(19.31)	(15.37)	(11.15)	(12.57)
$Growth_{i,t}$	0.050***	0.041***	0.319***	0.030***	0.033***	0.033***	0.035***	0.031***	0.039***	0.310***	0.018***	0.315***
	(11.21)	(10.25)	(17.31)	(13.11)	(8.31)	(9.31)	(10.31)	(8.65)	(10.00)	(6.11)	(7.06)	(8.97)
$Cf_{i,t}$	0.200***	0.209***	0.235***	0.117***	0.097***	0.131***	0.084***	0.107***	0.177***	0.182***	0.203***	0.194***
	(25.41)	(22.72)	(21.84)	(19.70)	(17.32)	(19.45)	(18.32)	(17.17)	(15.04)	(16.55)	(15.01)	(16.10)
$Debt_{i,t}$	-0.034***	-0.056***	-0.033***	-0.067***	-0.062***	-0.038***	-0.049***	-0.071***	-0.316***	-0.034***	-0.319***	-0.031***
	(-11.66)	(-12.15)	(-17.20)	(-15.23)	(-13.70)	(-16.07)	(-11.22)	(-7.20)	(-14.41)	(-13.77)	(-12.55)	(-13.50)
$Stk_{i,t}$	0.006*	0.009*	0.003	-0.004	0.030***	0.031	0.008***	0.019***	0.009***	0.001***	0.005***	0.011**
	(1.29)	(1.73)	(0.54)	(-0.73)	(4.39)	(0.26)	(5.42)	(4.23)	(12.31)	(11.55)	(4.65)	(2.46)
$Size_{i,t}$	-0.010	-0.013	0.110	-0.018**	-0.011**	-0.043*	-0.050**	-0.018**	0.015***	0.020**	0.008***	-0.026
	(-0.84)	(-0.05)	(0.24)	(-2.61)	(-2.51)	(-1.65)	(-2.24)	(-2.20)	(7.34)	(2.78)	(4.86)	(-0.52)
$Cons$	-0.044***	-0.105***	-0.014***	-0.101***	0.072***	-0.163*	0.075*	0.060***	-0.134*	-0.027***	-0.109***	0.039***
	(-10.20)	(-13.18)	(-15.41)	(-11.18)	(5.04)	(-0.93)	(1.82)	(6.44)	(-1.00)	(-6.10)	(-11.24)	(7.77)
Firm	control	control	control	control	control	control	control	control	control	control	control	control
Year	control	control	control	control	control	control	control	control	control	control	control	control
Sample size	2142	2142	2142	2142	2142	2142	2142	2142	2142	2142	2142	2142
Arellano–Bond test (m1)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Arellano–Bond test (m2)	0.551	0.516	0.480	0.422	0.399	0.544	0.489	0.422	0.524	0.408	0.387	0.460
Sargan test	0.804	0.750	0.799	0.825	0.711	0.810	0.891	0.806	0.658	0.670	0.755	0.801

Notes: This table reports the two-step GMM estimation results using unbalanced panel data. The dependent variable is R&D investment (Rd), while *Cons* represents the constant. Values in parentheses are standard errors corrected by Windmeijer (2005). ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 3. Financial constraints vs. innovation efficiency on R&D protection with proceeds from financial assets sales

	Invention ($IE = IE'$)				Utility model ($IE = IE''$)				Design ($IE = IE'''$)			
Variable	Eq. (1)	Eq. (5)	Eq. (6)	Eq. (7)	Eq. (1)	Eq. (5)	Eq. (6)	Eq. (7)	Eq. (1)	Eq. (5)	Eq. (6)	Eq. (7)
$Rd_{i,t-1}$	0.584*** (92.33)	0.602*** (110.21)	0.499*** (82.89)	0.510*** (103.06)	0.572*** (78.86)	0.561*** (79.99)	0.471*** (84.39)	0.501*** (80.06)	0.572*** (90.12)	0.569*** (82.12)	0.505*** (87.30)	0.543*** (99.06)
$Rd^2_{i,t-1}$	-0.054*** (-11.35)	-0.048*** (-17.33)	-0.051*** (-18.02)	-0.045*** (-14.35)	-0.062*** (-13.33)	-0.039*** (-9.44)	-0.022*** (-8.35)	-0.051*** (-15.02)	-0.019**** (-12.88)	-0.022*** (-10.02)	-0.012*** (-8.33)	-0.034*** (-10.01)
$Inv_{i,t}$	0.019*** (4.53)	0.37 (0.42)	0.027** (1.99)	-0.031 (-0.95)	0.033*** (3.81)	0.004* (1.45)	0.015*** (4.12)	-0.022 (-1.34)	0.002* (1.44)	-0.072 (-0.33)	0.055* (1.48)	0.011 (0.15)
$Inv_{i,t} \times FC_{i,t-1}$		-0.011*** (-6.03)		0.047 (0.40)		-0.070** (-2.41)		0.077 (0.60)		-0.053 (-0.16)		-0.002*** (-3.88)
$Inv_{i,t} \times IE_{i,t-1}$			0.048*** (5.17)				0.102** (2.76)				-0.117 (-0.84)	
Invi,t $\times FC_{i,t-1} \times IE_{i,t-1}$				0.091*** (4.50)				0.008*** (3.99)				0.277 (0.34)
$FC_{i,t-1}$	-0.093*** (-22.16)	-0.084*** (-19.17)	-0.077*** (-16.59)	-0.065*** (-16.75)	-0.076** (-16.33)	-0.079*** (-14.33)	-0.061*** (-13.77)	-0.074*** (-12.36)	-0.065*** (-13.77)	-0.091*** (-14.56)	-0.088*** (-12.78)	-0.059*** (-13.05)
$IE_{i,t-1}$	0.282*** (12.70)	0.310*** (14.66)	0.244*** (13.45)	0.275*** (19.06)	0.441*** (11.32)	0.398*** (18.22)	0.402*** (16.77)	0.455*** (10.25)	0.206*** (16.10)	0.297*** (13.17)	0.303*** (14.32)	0.311*** (15.94)
$Growth_{i,t}$	0.032*** (12.11)	0.100*** (9.34)	0.044*** (8.20)	0.056*** (9.77)	0.071*** (13.11)	0.079*** (12.21)	0.065*** (8.11)	0.051*** (8.10)	0.049*** (9.12)	0.050*** (7.06)	0.081*** (8.12)	0.062*** (7.29)
$Cf_{i,t}$	0.202*** (34.15)	0.218*** (30.11)	0.199*** (27.92)	0.202*** (24.33)	0.207** (21.86)	0.161*** (20.08)	0.211*** (22.18)	0.230*** (21.10)	0.173*** (20.28)	0.185*** (18.71)	0.206*** (16.67)	0.200*** (14.32)
$Debt_{i,t}$	-0.090*** (-9.16)	-0.077*** (-10.09)	-0.057*** (-9.08)	-0.062*** (-10.12)	-0.076*** (-6.11)	-0.070*** (-11.46)	-0.049*** (-10.21)	-0.053*** (-9.20)	-0.81*** (-10.05)	-0.086*** (-7.84)	-0.045*** (-8.19)	-0.051*** (-7.06)
$Stk_{i,t}$	0.044*** (5.01)	0.051*** (4.10)	0.034** (2.55)	0.028*** (3.16)	0.124* (1.95)	0.101*** (3.69)	0.022*** (5.04)	0.031* (1.99)	0.111 (0.56)	0.050*** (3.98)	0.045*** (3.36)	0.060*** (5.16)
$Size_{i,t}$	-0.007*** (-2.78)	-0.016* (-1.52)	-0.025** (1.97)	-0.043** (-1.99)	-0.029*** (-3.36)	-0.033** (-2.83)	0.028 (0.56)	0.046* (1.43)	-0.033* (-1.35)	0.041* (1.82)	0.054* (1.35)	0.101 (0.56)
$Cons$	0.013*** (5.42)	0.088*** (7.41)	-0.042*** (-5.50)	-0.036*** (-5.07)	0.120*** (8.11)	-0.050*** (-3.22)	-0.122* (-1.43)	-0.105*** (-3.11)	0.220*** (3.49)	-0.076*** (-10.11)	-0.107*** (-7.21)	0.050*** (4.77)
Firm	control	control	control	control	control	control	control	control	control	control	control	control
Year	control	control	control	control	control	control	control	control	control	control	control	control
Sample size	2142	2142	2142	2142	2142	2142	2142	2142	2142	2142	2142	2142
Arellano–Bond test (m1)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Arellano–Bond test (m2)	0.487	0.392	0.379	0.506	0.452	0.511	0.382	0.433	0.512	0.504	0.401	0.388
Sargan test	0.766	0.651	0.702	0.810	0.741	0.699	0.613	0.792	0.653	0.677	0.765	0.820

Notes: This table reports the two-step GMM estimation results using unbalanced panel data. The dependent variable is R&D investment (Rd), while Cons represents the constant. Values in parentheses are standard errors corrected by Windmeijer (2005). ***, **, and * denote significance at 1%, 5%, and 10% levels respectively.

5.4 Robustness test

For prudence sake, this section replaces the financial constraints index, proposed by Howell(2016), with the well-known KZ index (Kaplan and Zingales, 1997) to recheck the robustness of the findings. The robustness test results are reported in Tables A.2 and A.3 in the Appendix. The results are generally consistent with the main findings aforementioned.

As shown by Tables A.2 and A.3, R&D-intensive firms in general are inclined to protect their R&D investments by selling operating assets and financial assets, except the case of design patent with financial asset sales. R&D protection with asset sale is more pronounced for firms with high innovation efficiency, especially in the case of operating assets sales. Meanwhile, innovation efficiency has positive moderating effects on the R&D protection with asset sales while financial constraint negatively moderates the relationship between R&D investment and asset sales in the cases of invention and utility model. Furthermore, finically constrained firms with high innovation efficiency in utility model patent are found to protect their R&D investment with operating assets sale, and those with high innovation efficiency in invention patent and utility model patent.

Tables A.2 and A.3 also indicate some anomalies induced by the incorporation of KZ index. The coefficients on the interaction terms of financial constraint and asset sales (namely, $KZ \times OP$, $KZ \times Inv$) in Equation (5) are both significantly positive in the case of design patent. Similarly, the coefficients on financial constraint (KZ) and its interaction terms with asset sales (OP and Inv) in Equation (7) are positive for the case of design patent, while the coefficients in other cases are significantly negative. These anomalies suggest that financially constrained firms would like to increase rather than reduce R&D investment in the design patent case, which is contrary to the findings in other cases with innovative patents.

However, these anomalies are against the rationale that firms are less likely to protect superficial innovation rather than breakthrough innovation with asset sales, especially when they are financially constrained. It is worth noting that these anomalies should not affect the main findings of this paper, since it mainly focuses on cutting-edge innovations, namely innovation and utility model patents, rather than design patent with superficial novelty.

6. Conclusion

This study explores the determinants of R&D smoothing with financing asset sales from the perspectives of financial constraints and innovation efficiency. Specifically, this study examines the countervailing effects of financial constraints and innovation efficiency on R&D smoothing with financing asset sales using evidence from China's R&D-intensive firms spanning 2009 to 2016. The study considers three types of innovation efficiencies and two financial constraint indicators to ensure the broadest possible coverage. The empirical results obtained by the two-step GMM estimation are generally consistent and offer interesting findings regarding R&D investment activities.

R&D-intensive firms in China are generally found to protect their R&D investments by selling operating assets and financial assets. Meanwhile, financial constraints are found to have negative moderating effects on the relationship between R&D investments and financing asset sales, while innovation efficiency is found to positively moderate the latter. More interestingly, financially constrained firms with high innovation efficiency are found to increase their R&D investments with financing asset sales. These findings show that firms with high innovation efficiency are more likely to increase their R&D investments by selling assets, while those with high financial constraints are inclined to reduce their R&D investments unless they have high innovation efficiency. These findings are more pronounced for operating assets sales than for financial asset sales. The behavior of selling asset to protect R&D is more pronounced in firms with high efficiency in core innovation, namely, invention patents and utility model patents. These findings suggest that financially constrained firms do not adopt the R&D smoothing strategy with financing asset sales unless they possess high innovation efficiency. These firms are largely driven by the financing motivation to sell assets to satisfy needs more urgent than that of protecting R&D investments. By contrast, firms with high innovation efficiency, even when financially constrained, are mainly motivated by the efficiency incentive to increase their R&D investments with financing asset sales. As a result, prior R&D performance is a major driver for R&D smoothing with proceeds from asset sales, though financial constraints are an alternative motivation for financing through assets sales.

Overall, these findings further our understanding of the practice of R&D smoothing with financing asset sales by clarifying the roles of innovation efficiency and financial constraints. For one thing, the findings complement previous studies regarding R&D persistence, such as Ganter and Hecker (2013), Kang et al.(2017) as well as Coad (2019), by highlighting the opposite effects of innovation efficiency and financial constraints in R&D smoothing. For another, the findings provide new insights into asset divesture theory, including Arnold et al. (2018)and Edmans and Mann (2019), by identifying two under-researched motivations for financing asset sales. This study is expected to build a bridge between R&D investment management and asset divesture from the perspective of R&D smoothing with financing asset sales.

Our findings also have the following policy implications. Firstly, R&D-intensive firms should preserve financial flexibility in corporate liquidity management, since they are easily subject to financial constraints. Financial flexibility enables the firms to alleviate financial distress at a low cost when facing negative shocks. Financially flexible firms can keep their R&D expenditures relatively smooth, and therefore, avoid the very large adjustment costs of discontinued or suspended R&D investments. Secondly, R&D-intensive firms should consider the R&D smoothing strategy with financing asset sales if they are financially constrained. Asset sales are an alternative financing source for R&D investments in emerging markets with limited external financing opportunities like China. Although the proceeds may be limited, they are especially valuable as a way for R&D-intensive firms to protect their value-enhancing R&D investments without having to resort to more costly external financing. Finally, R&D-intensive firms should pay attention to their innovation efficiency when smoothing their R&D investments through financing asset sales. Innovation efficiency not only provides a strong motivation to sell assets for R&D smoothing, but also determines the innovation outcomes obtained from the R&D smoothing strategy. To a large extent, the performance of the R&D smoothing strategy with financing asset sales would depend on the firms' innovation efficiencies, especially for those who are financially constrained.

A limitation of this study may arise from its focus on the listed R&D-intensive firms in China, since other firms may also take part in R&D investments and asset sales. The primary reason is that the R&D-intensive firms have a more pronounced R&D orientation and a stronger incentive to smooth their R&D investments. Even though these firms publicly listed, they are easily susceptible to financial constraints due to the unique characteristics of R&D investments, especially in a typical emerging market like China. Financing asset sales provides these firms an alternative to protect their R&D investment if they are financially constrained. The research findings are expected to be further verified in more comprehensive studies. Moreover, the impact of R&D smoothing strategy with financing asset sales on firm performance deserves further study, which is beyond the scope this paper.

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Appendix

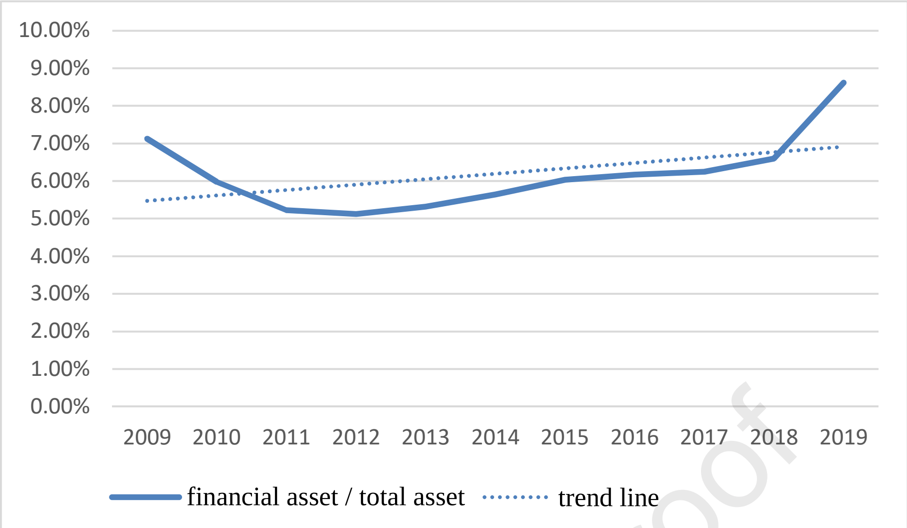

Figure A.1 Financial asset investment of firms in China

Notes: This figure shows the secular trend of the proportion of financial assets to total assets held by non-financial A-share listed companies in China from 2009 to 2019.

TableA.1. Variable definitions and description

Variable	Definition	Description	Variable	Definition	Description
Rd	R&D intensity	R&D spending/Total assets	Age	Firm age	Natural logarithm of the years between establishment date (or merger date) and the sample period
Rd_{t-1}^2	Quadratic adjustment costs of R&D investment	Squared value of lagged R&D intensity	FC	Dummy variable of financial constraints	*FC* = 1 if the value of F in Model 5 is positive; otherwise, *FC* = 0.
OP	Operating assets sales ratio	Net cash from disposing of fixed assets, intangible assets, and other long-term assets/Total assets	IE'	Innovation efficiency of invention	Application of patents for invention /R&D spending
Inv	financial assets sale ratio	Net cash from disposing of investment assets /Total assets	IE''	Innovation efficiency of utility model	Application of patents of utility model /R&D spending
Cf	Cash flow ratio	Net cash flow from operating activities /Total assets	IE'''	Innovation efficiency of design	Application of patents of designs/R&D spending
$Growth$	Investment opportunities	Average sales growth of last three years	θ	R&D smoothing degree by current operating assets sales	Absolute difference between the actual R&D investment of the firm and its theoretical value obtained in Equation (1), scaled by the standard deviation of those in the industry.
Stk	Net sock issue ratio	（Seasoned equity offerings + Rationed shares）/Total assets	θ'	R&D smoothing degree by financial assets sales	Absolute difference between the actual R&D investment of the firm and its theoretical value obtained in Equation (2), scaled by the standard deviation of those in the industry.
$Debt$	Net debt issue ratio	（Current debt - Lagged debt）/Total assets	$ASale$	Asset sales ratio	Sum of operating assets sale ratio and financial assets sale ratio
$Size$	Firm size	Natural logarithm of total assets	Lev	Level of debt	Total debt/Total assets
I	Investment spending	Cash paid to purchase fixed assets, intangible assets, and other long-term investments	$Sales$	Operating income	Sales from operating activities/Total assets

Table A.2. Financial constraints (KZ) vs. innovation efficiency on R&D protection with proceeds from operating assets sales

	Invention ($IE = IE^{'}$)				Utility model ($IE = IE^{''}$)				Design($IE = IE^{'''}$)			
Variable	Eq. (1)	Eq.(5)	Eq.(6)	Eq.(7)	Eq.(1)	Eq.(5)	Eq.(6)	Eq.(7)	Eq.(1)	Eq.(5)	Eq.(6)	Eq.(7)
$Rd_{i,t-1}$	0.046***	0.002***	0.597***	0.599***	0.013***	0.029***	0.008***	0.595***	0.566***	0.547***	0.573***	0.068***
	(95.33)	(94.20)	(108.32)	(99.25)	(110.41)	(97.32)	(108.05)	(89.39)	(82.46)	(79.05)	(88.72)	(75.30)
$Rd^2_{i,t-1}$	-0.061***	-0.055***	-0.064***	-0.059***	-0.066***	-0.050***	-0.051***	-0.048***	-0.052***	-0.044***	-0.039***	-0.042***
	(-17.33)	(-18.19)	(-18.11)	(-19.54)	(-23.33)	(-18.26)	(-21.44)	(-18.15)	(-10.33)	(-13.59)	(-12.35)	(-14.33)
$OP_{i,t}$	0.040***	0.046*	0.039**	0.051*	0.029***	0.042	0.127	-0.011**	0.007***	0.011*	0.056**	-0.045*
	(7.25)	(1.71)	(2.44)	(1.33)	(6.40)	(1.32)	(0.55)	(-2.62)	(5.08)	(1.95)	(2.33)	(-1.96)
$OP_{i,t} \times KZ_{i,t-1}$		-0.077**		-0.133		-0.034***		-0.107*		0.086***		0.003***
		(-2.94)		(-0.28)		(-4.05)		(-2.04)		(5.79)		(2.91)
$OP_{i,t} \times IE_{i,t-1}$			0.303***				0.426***				0.075***	
			(4.97)				(10.36)				(3.84)	
$OP_{i,t} \times KZ_{i,t-1} \times IE_{i,t-1}$				0.414				0.083***				0.103*
				(0.31)				(4.20)				(1.16)
$KZ_{i,t-1}$	-0.045*	-0.085	-0.032*	-0.065**	-0.009***	-0.010*	-0.018***	-0.026**	-0.012*	0.092	-0.025*	0.059*
	(-2.01)	(-0.17)	(-1.59)	(-2.35)	(-4.30)	(-1.33)	(-3.79)	(-2.36)	(-1.75)	(0.56)	(-2.01)	(1.47)
$IE_{i,t-1}$	0.237***	0.222***	0.195***	0.170***	0.357***	0.306***	0.508***	0.392***	0.092***	0.111***	0.123***	0.252***
	(13.31)	(12.80)	(10.24)	(9.05)	(9.48)	(8.33)	(11.12)	(8.30)	(5.29)	(9.53)	(12.54)	(9.74)
$Growth_{i,t}$	0.035***	0.104***	0.077***	0.073**	0.044***	0.081***	0.028***	0.056***	0.040***	0.100***	0.075***	0.036***
	(6.35)	(7.35)	(8.94)	(15.86)	(14.67)	(22.18)	(15.32)	(8.04)	(6.35)	(7.02)	(8.94)	(13.28)
$Cf_{i,t}$	0.237***	0.173***	0.062***	0.061***	0.049***	0.138***	0.085***	0.028***	0.049***	0.029***	0.032***	0.038***
	(13.31)	(9.04)	(4.67)	(8.24)	(5.55)	(7.43)	(9.11)	(14.78)	(5.55)	(6.77)	(7.93)	(7.23)
$Debt_{i,t}$	-0.027***	-0.022***	-0.033**	-0.026***	-0.020***	-0.031***	-0.025***	-0.019***	-0.018***	-0.028***	0.022***	-0.031***
	(-19.20)	(-25.75)	(-14.27)	(-26.03)	(-21.06)	(-20.75)	(-13.05)	(-18.50)	(-21.06)	(-22.78)	(-22.22)	(-18.06)
$Stk_{i,t}$	0.083***	0.077***	0.079***	0.065***	0.022*	0.302	0.096	0.061***	0.076*	0.036**	0.063*	0.051
	(25.53)	(26.86)	(28.43)	(21.73)	(1.93)	(0.37)	(0.33)	(5.85)	(1.79)	(2.47)	(1.99)	(0.47)
$Size_{i,t}$	-0.078***	-0.079**	-0.076*	-0.053	-0.079***	-0.090***	-0.045***	-0.049***	-0.105***	-0.082***	-0.076***	0.880***
	(-3.25)	(-2.13)	(-1.15)	(-0.36)	(-9.21)	(-8.43)	(-5.11)	(-6.59)	(-10.44)	(-7.50)	(-8.47)	(21.92)
$Cons$	0.039***	0.036**	-0.018*	-0.023*	0.021***	-0.025*	-0.020***	-0.031***	0.095***	-0.109***	0.056***	-0.062*
	(8.10)	(2.64)	(-1.21)	(-1.07)	(6.62)	(-1.63)	(-5.08)	(-8.61)	(4.11)	(-6.59)	(8.11)	(-1.18)
Firm	control	control	control	control	control	control	control	control	control	control	control	control
Year	control	control	control	control	control	control	control	control	control	control	control	control
Sample size	2142	1933	2142	1933	2142	1933	2142	1933	2142	1933	2142	1933
Arellano–Bond test (m1)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Arellano–Bond test (m2)	0.300	0.296	0.288	0.305	0.287	0.301	0.308	0.299	0.332	0.351	0.295	0.344
Sargan test	0.061	0.708	0.796	0.746	0.903	0.045	0.899	0.812	0.541	0.477	0.001	0.581

Notes: This table reports the two-step GMM estimation results using unbalanced panel data. The dependent variable is R&D investment (Rd), while KZstands for financial constraints. Values in parentheses are the standard errors corrected by Windmeijer (2005). ***, **, and * denote significance at 1%, 5%, and 10% levels respectively.

Table A.3. Financial constraints (KZ) vs. innovation efficiency on R&D protection with the proceeds from financial asset sales

	Invention ($IE = IE'$)				Utility model ($IE = IE''$)				Design($IE = IE'''$)			
Variables	Eq. (1)	Eq.(5)	Eq.(6)	Eq.(7)	Eq.(1)	Eq.(5)	Eq.(6)	Eq.(7)	Eq.(1)	Eq.(5)	Eq.(6)	Eq.(7)
$Rd_{i,t-1}$	0.055***	0.588***	0.549***	0.582***	0.559***	0.572***	0.570***	0.040***	0.023***	0.578***	0.021***	0.019***
	(98.07)	(86.97)	(74.39)	(69.82)	(83.45)	(93.58)	(82.30)	(105.10)	(87.90)	(74.38)	(110.34)	(73.66)
$Rd^2_{i,t-1}$	-0.039***	-0.036***	-0.018***	-0.023***	-0.021***	-0.025***	-0.049***	-0.056***	-0.055***	-0.057***	-0.058***	-0.061***
	(-15.10)	(-12.64)	(-12.21)	(-16.07)	(-11.62)	(-17.63)	(-14.06)	(-14.51)	(-18.02)	(-14.00)	(-21.57)	(-18.31)
$Inv_{i,t}$	0.036***	0.122*	0.051*	-0.110*	0.018***	-0.025*	0.034*	-0.023*	0.206	0.019***	0.020**	-0.041*
	(3.73)	(1.48)	(1.68)	(-1.36)	(4.53)	(-1.71)	(1.07)	(-1.16)	(0.49)	(2.94)	(2.37)	(-1.59)
$Inv_{i,t} \times KZ_{i,t-1}$		-0.082***		-0.052***		-0.112**		-0.048**		0.258*		0.054*
		(-3.02)		(-4.10)		(-2.23)		(-2.71)		(1.37)		(1.80)
$Inv_{i,t} \times IE_{i,t-1}$			0.208***				0.059***				0.263**	
			(4.93)				(4.16)				(2.02)	
$Inv_{i,t} \times KZ_{i,t-1} \times IE_{i,t-1}$				0.022***				0.151**				0.120
				(4.07)				(2.32)				(0.35)
$KZ_{i,t-1}$	-0.032**	-0.016*	-0.053*	-0.036***	-0.022*	0.002	-0.096	0.51	-0.045**	-0.039***	-0.041***	0.079*
	(-2.38)	(-1.55)	(-1.99)	(-5.47)	(-1.93)	(0.37)	(-0.33)	(0.85)	(-2.79)	(-10.19)	(-5.54)	(1.26)
$IE_{i,t-1}$	0.301***	0.155***	0.173***	0.062***	0.361***	0.049***	0.208***	0.385***	0.028***	0.057***	0.146***	0.173***
	(26.15)	(10.13)	(9.04)	(4.67)	(8.24)	(5.55)	(7.43)	(11.11)	(14.78)	(11.48)	(6.06)	(9.04)
$Growth_{i,t}$	0.078***	0.059***	0.057***	0.033***	0.074***	0.052***	0.081***	0.055***	0.049***	0.028***	0.037***	0.077***
	(10.02)	(8.90)	(7.51)	(12.10)	(13.20)	(9.00)	(13.58)	(8.56)	(12.01)	(11.00)	(10.29)	(18.25)
$Cf_{i,t}$	0.136***	0.116***	0.164***	0.125***	0.220**	0.121**	0.111	0.233***	0.228***	0.012	0.062***	0.052***
	(21.84)	(11.00)	(20.29)	(12.22)	(12.24)	(13.43)	(14.51)	(13.29)	(15.42)	(11.18)	(9.31)	(3.60)
$Debt_{i,t}$	-0.236***	-0.130***	-0.229***	-0.132***	-0.204***	-0.117***	-0.203***	-0.109***	-0.134***	-0.047***	-0.101***	0.059***
	(-24.97)	(-20.55)	(-31.23)	(-18.72)	(-16.10)	(-27.55)	(-21.06)	(-30.49)	(-15.00)	(-16.06)	(-11.24)	(12.72)
$Stk_{i,t}$	0.124***	0.033***	0.114**	0.098**	0.081*	0.073**	0.065***	0.083*	0.134	0.204	0.109*	0.169**
	(5.43)	(3.42)	(2.41)	(2.75)	(1.04)	(2.07)	(5.82)	(1.34)	(0.57)	(0.46)	(1.24)	(2.72)
$Size_{i,t}$	-0.125*	-0.051**	0.129*	-0.075	-0.006***	-0.096*	-0.047**	0.010*	0.104**	-0.231	-0.152**	0.235*
	(-1.59)	(-2.50)	(1.52)	(-0.28)	(-4.07)	(-1.41)	(-2.55)	(1.06)	(2.49)	(-0.30)	(-2.13)	(1.16)
$Cons$	-0.066**	0.113*	-0.075	-0.004	0.164***	0.057*	-0.050***	0.019***	-0.141*	0.023***	-0.157***	0.224***
	(-2.63)	(1.05)	(-0.33)	(-0.35)	(11.92)	(1.97)	(-8.43)	(5.43)	(-1.59)	(3.27)	(-7.18)	(4.79)
Firm	control	control	control	control	control	control	control	control	control	control	control	control
Year	control	control	control	control	control	control	control	control	control	control	control	control
Sample size	2142	1933	2142	1933	2142	1933	2142	1933	2142	1933	2142	1933
Arellano–Bond test (m1)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Arellano–Bond test (m2)	0.384	0.297	0.420	0.286	0.346	0.405	0.391	0.299	0.394	0.308	0.339	0.385
Sargan test	0.881	0.534	0.868	0.611	0.076	0.910	0.885	0.906	0.617	0.692	0.528	0.604

Notes: This table reports the two-step GMM estimation results using unbalanced panel data. The dependent variable is R&D investment (Rd), while KZstands for financial constraints. Values in parentheses are the standard errors corrected by Windmeijer (2005). ***, **, and * denote significance at 1%, 5%, and 10% levels respectively.

Highlights

- We examine the determinants of R&D smoothing with financing asset sales
- R&D intensive firms are found to protect their R&D investments by selling assets
- Financial constraints prohibit firms from adopting the R&D smoothing strategy
- Firms with high innovation efficiency are more inclined to adopt the strategy
- Innovation efficiency is regarded as the major incentive for adopting the strategy

Author Statement

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We have seen and approved the final version of the manuscript being submitted. We warrant that the article is the authors' original work, hasn't received prior publication and isn't under consideration for publication elsewhere. We have followed ethics guidelines.

ii. Disclosure of Conflicts of Interest

We declare that we have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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v. Authorship Contributions

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