Real Asset Liquidity and Corporate Innovation

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ABSTRACT

Utilizing a real asset liquidity index and U.S. patent data from 1986-2006, we demonstrate that real asset liquidity promotes corporate innovation, allowing us to reconcile the two opposing views on their relation. In view of the possible endogeneity problem, we use instrumental variable and difference-in-difference approaches to reconfirm the positive relation between the two. This positive impact of real asset liquidity on innovation strengthens when firms face more financial constraints and more product-market competition.

Keywords: Real Asset Liquidity, Innovation, Stock Liquidity, Financial Constraint, Market Competition

JEL Classifications: G10, G32, G39

"To compete effectively in international markets, a nation's businesses must continuously innovate and upgrade their competitive advantages. Innovation and upgrading come from sustained investment in physical as well as intangible assets."

Michael E. Porter, 1992, Capital disadvantage: America's failing capital investment system. *Harvard Business Review* 70, 65-82.

1. Introduction

Innovation is the foundation of long-term economic growth and competitive advantage. Given the importance of innovation for a firm's long-term development, there has been a number of discussions on the underlying factors for corporate innovations, including CEO overconfidence (Hirshleifer, Low, and Teoh, 2012), institutional ownership (Aghion, Reenen, and Zingales, 2013), product-market competition (Gu, 2016; Aghion, Bloom, Blundell, Griffith, and Howitt, 2005), accounting conservatism (Chang, Hilary, Kang, and Zhang, 2013), stock liquidity (Fang, Tian, and Tice, 2014), religion (Chen, Podolski, Rhee, and Veeraraghavan, 2014), economic policy uncertainty (Bhattacharya, Hsu, Tian, and Xu, 2015; Mukherjee, Singh, and Žaldokas, 2017), banking deregulation (Chava, Oettl, Subramanian, and Subramanian, 2013), etc. However, investigations into how a firm's real asset liquidity affects its innovation have been surprisingly limited.

A real asset is liquid if it can be converted into cash quickly at a low cost. Real asset liquidity affects a firm's ability to redeploy its real assets for alternative uses and affects its operating flexibility and uncertainty when responding to a changing business environment (Almeida and Campbello, 2007, Ortiz-Molina and Phillips, 2014; Kim and Kung, 2016).[2] In addition, a liquid

[2] In this paper, we use real-asset liquidity, real-asset tangibility, and real-asset redeployability interchangeably. Real-asset liquidity is used in Ortiz-Molina and Phillips (2014), real-asset tangibility is used in Almeida and Campbello (2007) and real-asset redeployability is used in Kim and Kung (2016). These three variables all measure how fast and how costly a firm's real asset can be converted into liquid assets.

real asset can serve as collateral to enhance a firm's debt capacity and reducing financing frictions (Almeida and Campbello, 2007; Shleifer and Vishny, 1992). The operating and funding flexibility provided by the firm's liquid real assets may serve as a critically important instrument that influences the firm's corporate decisions.

Interestingly, prior research offers two competing views regarding the impact of real asset liquidity on innovation. One view is built on the cost-of-capital perspective, which recognizes that firms with high real asset liquidity have more debt capacity and lower costs of debt (Almeida and Campbello, 2007; Williamson, 1988; Shleifer and Vishny, 1992; and Benmelech and Bergman, 2008, 2009). Ortiz-Molina and Phillips (2014) find that real asset liquidity increases a firm's ability to redeploy its real assets for alternative uses and thus its operating flexibility. Through this channel, real asset liquidity further reduces a firm's cost of equity capital. Hence, the cost-of-capital perspective predicts that higher real asset liquidity helps firms gain access to external financing at a lower cost of capital, which facilitates their innovation activities.

Another view is that real asset liquidity may impede a firm's innovation through the effect of stock liquidity. Fang, Xuan, and Tice (2014) find that stock liquidity impedes innovation activities because of increased exposure to hostile takeovers and a higher presence of institutional investors while Gopalan, Kadan, and Pevzner (2012) compile a positive relation between asset liquidity and stock liquidity. Combining these two arguments, it becomes obvious that real asset liquidity negatively affects corporate innovations.

In the presence of these two competing views, empirical evidence compiled in this study provides strong support for the positive relation between real asset liquidity and innovation. Using real-asset tangibility measures used in Almeida and Campbello (2007) and the National Bureau of Economic Research (NBER) patent dataset from 1986-2006, we document a positive and significant association between the two.[3] Our results remain robust across alternative measures of

[3] The main reason to choose sample period up to 2006 is to avoid the influence of subprime crisis.

innovation input and output, and remain unchanged when we control for omitted variable problems. In view of possible endogeneity, we use an instrumental variable (IV) and difference-in-difference (DiD) approaches to reexamine the positive relation between the two. In the IV approach, we follow Campello and Giambona (2013) to introduce two IVs: industry-level real-asset resale value and industry-level real-asset tangibility to estimate the model via two-stage least square estimation. Our results remain unchanged. In addition, we again follow Campello and Giambona (2013) to take the sale of military bases by the U.S. government subsequent to the end of the cold war in 1992 as an exogenous event for real-asset liquidity shock and conduct a DiD analysis. This sale of military bases increased the supply of real estate and further push down the liquidation value of real assets as well as real asset liquidity. Especially, the small-size firms are affected by the reduction of real asset liquidity more than the large-size firms. In this DiD analysis, the below-median small-size firms are regarded as treated firms, and above-median large size firms are regarded as untreated firms. In this DiD analysis, overall, we still find that real-asset liquidity positively affects innovation.

Wefurther investigate whether the association between real asset liquidity and corporate innovations varies in the level of financial constraint and product-market competition. When a firm is financially constrained, an increase in real asset liquidity provides it with an additional source of funding and reduces the level of financial constraints (Almeida and Campello, 2007). To capture the financial constraint, we follow Edwards, Schwab, and Shevlin (2016) and Lyandres and Palazzo (2016) to employ three firm-specific financial constraint measures, *ΔKZ Rank, ΔZ-score Rank,* and dividend payment dummy. We find that a more financially constrained firm would benefit more from this funding improvement. This funding improvement due to the increase of real asset liquidity will facilitate innovations and trigger more investment in R&D. Therefore, we predict that financial constraint strengthens the positive association between the two, and this prediction is strongly supported by our empirical evidence.

Because product-market competition plays a significant role in innovation (Gu, 2016; Aghion et al., 2013), we also examine whether the intensity of this competition affects a firm's innovation propensity. Galasso and Simcoe (2011) observe that the link between CEO overconfidence and performance is stronger when product-market competition is more intense. Lyandres and Palazzo (2016) find that cash holdings in the process of innovation play a strategic role when product-market competition becomes more intense. We use the the Herfindahl-Hirschman Index (HHI), number of rival firms in the same industry (*NRivFirm*), and financial slacks of rival firms in the same industry (*FSRivFirm*) as proxies for product-market competition. Our empirical results indicate that the positive association of real asset liquidity and innovation increases as product-market competition becomes more intense. This evidence empirically confirms the escape-from-competition hypothesis that a more intense product-market competition causes the firm to engage in innovation to differentiate itself from other competitors once it has more financial support. Our results also show that in a more competitive product market, the increase of real-asset liquidity both increases the innovation input and output.

This paper contributes to the literature in three aspects. First, this paper is the first to confirm that the firm's overall real-asset liquidity enhances corporate innovation, allowing us to reconcile the two opposing views on their relation.[4] Prior literature discusses either the impact of real asset tangibility (redeployability) on ordinary capital investment (Almeida and Campello, 2007) or the impact of internal financial liquidity (cash holdings) on corporate innovations (Lyandres and Palazzo, 2016; Wang, Wei, and Zhang, 2016). However, none of them empirically examines the association between the firm's overall real asset liquidity and innovation.

In addition, our paper further improves the results of Alderson and Betker (1996), who demonstrate that liquidation costs and R&D expenditure are positively related across firms. For robustness check, we adopt the firm-specific measure of asset liquidity of Almeida and Campbello (2007), which essential measure the liquidation value of a unit dollar invested in account

[4] The real-asset liquidity index used in Almeida and Campello (2007) is adopted from Berger et.al. (1996) and it essentially captures a firm-level measure of expected asset liquidation values.

receivables, inventory, net of PPE, and cash and equipment, to examine the association between real asset liquidity and innovation output. We confirm that the positive association between real asset liquidity and innovations is positive and robust in both innovation input and output.

Second, this paper provides additional evidence that a financial constraint weakens the marginal impact of real asset liquidity on innovations. Previous research (Brown, Martinsson, and Petersen, 2012; Almeida, Hsu, and Li, 2013) only focuses on the association between financial constraint and innovation, while the influence of real asset liquidity is overlooked. By focusing on the role of real asset liquidity, we expand the results of Brown et al. (2012) and Almeida et al. (2013).

Third, this paper considers product-market competition in examining the association between real asset liquidity and innovation. Our results provide additional insights to those compiled by Galasso and Simcoe (2011) and Aghion et al. (2005, 2013), while they discuss either the impact of product-market competition on the association between CEO overconfidence and innovation or the impact of product-market competition itself on innovation.

The rest of the paper is organized as follows. Section 2 discusses our data, including variable definition and their summary statistics. Section 3 reports empirical methods and results. Section 4 reports the results of our analyses on the impact of financial constraints and product-market competition. Section 5 reports the results of robustness checks, including endogeneity problem. In the second half of Section 5, we reconcile the competing views on the relation between real asset liquidity and corporate innovation. Section 6 concludes the paper.

2. Data

In this section, we describe the data source and variable definitions. Then, we provide the summary statistics of the variables used in empirical study.

2.1. Data Source and Variable Definition

Our data are collected from Compustat and the U.S. patent data file compiled by NBER. In measuring corporate innovation, the R&D expenditure data are from Compustat; patent counts and patent citations are from the NBER data file, which contain 3.2 million patents and 23.6 million citation counts. The NBER patent dataset provides (among other items) annual information on patent assignee names, the number of patents, the number of citations received by each patent until 2006, and the year that the patent application was filed. We choose the sample period up to 2006 because the subprime crisis occurred in 2007 and this event may distort the firms' innovation decisions. We only utilize patents filed by U.S. firms for our analysis. Finally, we delete the samples of financial institutions (e.g., SIC from 6000 to 6999) and utilities (SIC from 4900 to 4999). The final samples cover 5,829 firms during the period 1986 to 2006.

2.1.1. Measuring Innovation

Following Galasso and Simcoe (2011), Hirshleifer et al. (2012), and Sapra et al. (2014), we employ the logarithm of R&D expenditure in the Compustat database as a basic measure of innovation input. For the innovation output, the first measure of innovation is *patent counts,* which are the number of patent applications based on the firm year. To link the patent data with Compustat, we take advantage of the fact that each assignee in the NBER patent dataset is given a unique and time-invariant identifier.

As explained by Griliches, Pakes, and Hall (1987), patent counts cannot perfectly capture innovation success, because the nature of patents varies widely in technological and economic importance. A measure that exhibits the important economic meaning of a patent is its citations, which could identify prior knowledge upon which a patent builds and delimits the scope of the property rights awarded to the inventor. The innovation literature has often employed the number of forward citations received by a patent as an indirect measure of patent value (for example, Pakes and Griliches, 1980; Hall, Jaffe, Trajtenberg, 2005; Harhoff, Narin, Scherer, and Vopel, 1999;

Aghion et al., 2013). Hence, the second measure of innovation output is built on patent citations.[5]

We employ two different methods of patent citations to adjust the inherent time-truncation bias, because there is a lag between the time of patent application and the time of citation (Hall, Jaffe, and Trajtenberg, 2001, 2005; Hirshleifer et al., 2012; Seru, 2014). Hence, we introduce two measures denoted by *ACWCP1* and *ACWCP2*, respectively. *ACWCP1* captures the citation count of each patent multiplied by the weighting index of Hall et al. (2001, 2005), where the weighting index is given in the NBER U.S. patent data file. We aggregate the weighted citations across all patents based on the firm application year. *ACWCP2* measures the citation count of each patent by the average citation counts of total patents within the same technology class and application year. We then aggregate the adjusted citation counts across all patents on the application firm-year.

2.1.2. Measuring Real-Asset Liquidity

In measuring real asset liquidity, we employ the "firm-specific" liquidation value, suggested by Almeida and Campbello (2007) and Berger et al. (1996) using the following formula:

$$Real\ Asset\ Liquidity = 0.715 \times RECT + 0.547 \times INV + 0.535 \times CAP + Cash$$

where *RECT* is measured by total receivables (Item *RECT* in Compustat). *INV* is identified as firm's inventory (Item *INVT* in Compustat). *CAP* is calculated as property, plant, and equipment (Item *PPENT* in Compustat). Following Almeida and Campbello (2007) and Berger et al. (1996), we include value of cash holdings *Cash* (Item *CHE* in Compustat) to this measure and divided all variables by total book assets.

2.1.3. Control Variables

[5] Previous studies employ the number of forward citations of a patent as an indirect measure of patent value (Pakes and Griliches, 1980; Hall et al., 2005; Harhoff et al., 1999; and Aghion et al., 2013). Trajtenberg (1990) notes that citation counts are connected to the social value generated by the innovation. Galasso and Simcoe (2011) demonstrate that patent citations identify previous recognition that a patent generates and that the scope of property rights granted to investors is delimited by patent citations.

To explain R&D expenditure and patent-generating activities, we control for firm size, capital intensity, firm age, ROA, leverage, and Tobin's Q.[6] These control variables are widely used in previous studies, e.g.:Hall and Ziedonis (2001), Aghion et al. (2013), Hirshleifer et al. (2012), and Amore, Schneider, and Žaldokas (2013). Firm size is measured by sales (Item *SALE* in Compustat); capital intensity is measured by the ratio of property, plant, and equipment (*PPEGT*) to the number of employees (Item *PPEGT* /Item *EMP* in Compustat). The firm's age is the number of years that the firm has been in Compustat. *ROA* is measured by the ratio of earnings before interest, tax, depreciation, and amortization (*EBITDA*) to book assets (Item *EBITDA* /Item *AT* in Compustat). Sales growth is measured by the firm's sales in the current year divided by the firm's sales in the previous year, where sales are measured as *SALE* (Item *SALE* in Compustat). Leverage is measured by the ratio of total debt to book assets, where total debt is the sum of long-term debt and current liability ((Item *DLTT* + Item *DLC*) /Item *AT* in Compustat). *Tobin's Q* is measured by the ratio of market value to book assets ((Item *AT* - Item *CEQ* - Item *TXDB* + Item *CSHO* × Item *PRCC*) /Item *AT* in Compustat). We control for year- and industry-fixed effects at the two-digit SIC in a panel regression.

2.2. Summary Statistics

Table 1 presents summary statistics of all samples, which include the measures of innovation, real asset liquidity, and the firm characteristics. Regarding the measures of innovation, Panel A presents R&D expenditure, patent counts, adjusted patent citations, *ACWCP1*, and *ACWCP2*. There are two weighting schemes to adjust for patent citations. The first variable, *ACWCP1*, is obtained by multiplying the citation counts of each patent by "the weighting index" provided by the NBER patent data file (Hall et al., 2001, 2005) and then aggregating the weighted citations across all patents on the firm-application year level. The second measure, *ACWCP2*, is the citation counts of each patent scaled by average citation counts of total patents in the same technology class and

[6] Detailed definitions of the control variables are summarized in the Appendix.

application year. We aggregate the adjusted citation counts across all patents of the applied firm during the year (Hirshleifer et al., 2012). The mean logarithm of R&D expenditure is 2.583, the patent count is 30.693, *ACWCP1* is 451.8, and the mean of *ACWCP2* is 30.845. The mean of innovation measures is comparable to those compiled by Galasso and Simcoe (2011) and Hirshleifer et al. (2012). In addition, the distributions of patent counts and adjusted patent citations (*ACWCP1* and *ACWCP2*) are highly skewed, which is consistent with the previous literature (e.g.: Hirshleifer et.al. (2012), Hall et.al. (2015), Blanco and Wehrheim (2017), Lyandres and Palazzo (2016), and Chang et.al. (2015)).

Panel B presents the results of the real asset liquidity index (*AL index*). The mean of the real asset liquidity index is 0.456, which is similar to Almeida and Campell (2007) by 0.526. Panel C presents firm characteristics, which are similar to those in the literature (Aghion et al., 2013; Galasso and Simcoe, 2011; Hirshleifer et al., 2012; Amore et al., 2013). The financial constraint is measured by the *△KZ Rank, △Z-score Rank, and dividend dummy*, which capture the level of financial constraint. Product market competition is measured by Herfindahl-Hirschman Index (*HHI*), which are based on the idea that competition increases in the substitutability of future products (Syverson, 2004)[7], number of rival firms in the same industry (*NRivFirm*), and financial slacks of rival firms in the same industry (*FSRivFirm*). The final two measures capture that more competitors or more financial slacks of competitors in the same market imply more intense product-market competition

Table 2 presents the matrix of the Spearman correlation coefficients that demonstrate relations among innovation, real asset liquidity index, and firm characteristics. Most correlation coefficients differ significantly from zero at the 1% level. Specifically, the real asset liquidity index is significantly and negatively correlated with Ln (1+*R&D expenditure*), Ln (1+*patent counts*), Ln

[7] We multiply (-1) to HHI to make these measures be positively correlated with the degree of product-market competition.

(1+*ACWCP1*), and Ln (1+*ACWCP2*). These findings provide preliminary support of our hypothesis.

[Insert Tables 1 and 2]

3. Empirical Method and Empirical Results

Following Sapra, Subramanian, and Subramanian (2014), Aghion et al. (2013), and Galasso and Simcoe (2011), we employ a panel regression model with Petersen's (2009) clustered standard errors by firm and year to estimate the continuous dependent variable of innovation (i.e., R&D expenditure), patent counts and patent citations. R&D expenditure is used to measure the input of innovations, and the patent counts and patent citations are used to measure the output of innovations. We take these two innovation measures along with the estimation approaches to provide robust empirical results in the later sections.

3.1. Empirical Method

We employ panel regressions with two-way clustered standard errors for firm and year, as suggested by Petersen (2009), to examine the association between real asset liquidity and future innovations for three periods. The model specification is:

$$y_{i,t+n} = AL\ index_{i,t}\beta_1 + \mathbf{X}_{i,t}\boldsymbol{\beta} + \mu_i + \upsilon_t + \varepsilon_{i,t}, \quad (1)$$

where i indicates firm, t indicates time, and n equals one, two, and three; $y_{i,t+n}$ is the inputs or outputs of innovation n years ahead, such as the logarithm of one plus R&D expenditure n years ahead; $AL\ index_{i,t}$ is the real asset liquidity index, μ_i is the industry-fixed effect; υ_t is the time-fixed effect; $\varepsilon_{i,t}$ is the error term; and $\mathbf{X}_{i,t}$ is the vector of control variables. Following Galasso and Simcoe (2011), Aghion et al. (2013), and Hall and Ziedonis (2001), we include size and capital intensity (i.e., capital-labor ratio). Similar to Hirshleifer et al. (2012) and Amore et al. (2013), we add the logarithm of firm age, ROA, sales growth, leverage, and Tobin's Q into our regression.

3.2. Empirical Results

To examine the impact of real asset liquidity on innovation, the R&D input, measured by the logarithm of one plus R&D expenditure in one year, is taken as the dependent variable. The results in Table 3 indicate that real asset liquidity index (*AL index*) is positively associated with expenditure on R&D. In model (1), from the regression coefficient, we find the preliminary result that *AL index* is positively associated with R&D expenditure by approximately 1.893, which is significant at the 1% level. The product of this coefficient (1.893) and a one standard deviation change in real asset liquidity, 0.137, from Table 1 shows that the real asset liquidity increases R&D expenditure in one year by around 26%.[8]

In models (2) and (3), we replace the dependent variable with the logarithm of one plus R&D expenditure in two and three years, respectively. We do not simply use R&D expenditure for one year in order to capture a comprehensive innovation measure and to moderate the potential distortion from the use of a single-year data. The qualitative and quantitative conclusions are similar to those in model (1). The coefficient in model (2) shows that firms with higher real asset liquidity increase ln (1+R&D expenditure) by approximately 1.058 in two years. In model (3), considering the logarithm of one plus R&D expenditure in three years causes a modest increase in the coefficient to 1.960. This result shows a robust evidence that the positive association of real asset liquidity on innovation is not only significant in one-year period, but also in coming three-year period.

We further find that the coefficients on most control variables are consistent with previous studies in that younger firms, poor operating performance, more industry growth, less leverage, and high Tobin's Q are related to higher R&D spending (Galasso and Simcoe, 2011; Hirshleifer et al., 2012; Amore et al., 2013).

[Insert Table 3]

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[8] We also alternatively use R&D/Assets and R&D/Sale to measure innovation output. The results are similar to using in Ln (1+R&D expenditure) as dependent variable.

In Table 4 we examine whether real asset liquidity increases the fruits of innovation activity. We use the logarithm of one plus patent counts and logarithm of one plus adjusted patent citations of a firm in one year as a dependent variable. The control variables are identical to those in Table 3 (Galasso and Simcoe, 2011; Hirshleifer et al., 2012; Amore et al., 2013). The empirical results support the hypothesis that firms with high real asset liquidity promote more innovation.

In Panel A of Table 4, the dependent variable is logarithm of one plus patent counts. Model (1) demonstrates that a unit increase in *AL index* causes an increase in the ln (1+number of patents) by 0.955. In models (2) and (3), the coefficients of real asset liquidity remain positive and significant after considering the number of patent counts in two and three years. Interestingly, the coefficients on real asset liquidity increase over time, from 0.955 in model (1) to 1.047 in model (3). Taken together, this empirical evidence shows that real asset liquidity has a persistently positive impact on patent counts. This evidence suggests that liquid real assets facilitate the firm in continuing its R&D activities without interruption and generating more patents in future years. Panels B and C present the results when logarithm of one plus *ACWCP1* and logarithm of one plus *ACWCP2* are used as dependent variables and show whether higher real asset liquidity is related to more patent citations. The control variables introduced are widely used in previous studies (Galasso and Simcoe, 2011; Amore et al., 2013). The empirical results suggest that firms with higher real asset liquidity are positively related to *ACWCP1*. Model (1) suggests that a one-unit increase in *AL index* enhances patent citations by approximately 1.263. By replacing the dependent variable with *ACWCP1* two and three years ahead, model (2) and model (3) show that the coefficients of the real asset liquidity index remain significantly positive on patent citations.

Panel C presents empirical results with *ACWCP2* as the dependent variable. The empirical results in model (1) are consistent with the findings in Panel B, which exhibit a significantly positive relation between *AL index* and patent citations at the 1% level with a coefficient of 1.045. The coefficients of *AL index* in model (2) and model (3) are positive after substituting one year with two and three years. This indicates that firms with higher real asset liquidity lead in new directions and are thus more likely to receive many citations from original patents.

[Insert Table 4]

3.3. Additional control variables

Abundant studies report that CEO compensation is closely tied to the firm's innovation. For example, when the compensation scheme with stock options motivates CEO to launch more innovation activities (Cheng, 2004; Manso, 2011; Sheikh, 2012; Ederer and Manso, 2013; Chen, Chen and, Chu, 2014). In addition, CEOs approaching retirement may lower R&D expenditures (Cheng, 2004). Furthermore, the firms in the innovative industry or the firms in highly-intensive M&A activities industry would aggressively invest in innovation (Hirshleifer et al., 2012; Bena and Li, 2014; Zhao, 2009). Therefore, we include the variables capturing CEOs compensation, CEO characteristics, M&A intensive industry, and industry-level R&D growth in the regression.

CEOs compensation includes three components: CEO cash compensation, CEO delta and CEO vega. *CEO cash compensation* is measured by the paid in cash. *CEO delta* is measured by logarithm of the dollar sensitivity of CEO compensation portfolio to 1% change in the firm's stock price. *CEO vega* is measured by logarithm of the dollar sensitivity of CEO compensation portfolio to 1% change in the firm's stock return volatility. Next, CEO characteristics include CEO tenure and CEO age. *CEO tenure* is measured by the number of years that CEO work in the firm while *CEO age* is measured by CEO's age as of the sample year. Furthermore, #*M&A activities* is the average number of industry-level M&A activities, which is measured by the logarithm of one plus the number of M&A activities in the industry. Industry-level R&D growth (*Ind. R&D growth)* is measured by the logarithm of the ratio of $R\&D_{t+1}$ to $R\&D_t$ based on the three-digit SIC level (*XRD* in Compustat).

Table 5 reports the results that regress *AL index* on innovation input (e.g., R&D expenditure) and innovation output (e.g., Patent counts, ACWCP1, and ACWCP2) considering CEOs compensation, CEO characteristics, #M&A activities, and Ind. R&D growth as additional control variables. We also include all control variables as in Table 3 and industry-year fixed effect. The coefficients on *AL index* are all positive and significant at one percent level across model (1) to model (4). The finding suggests that AL index has a significant impact on innovation inputs and innovation outputs after we control for all the relevant variables.

[Insert Table 5]

4. Financial Constraints and Product-Market Competition

4.1. Financial Constraints

The level of financial constraint is important for R&D-intensive firms (Li, 2011; Almeida and Campell, 2007). If a firm encounters a funding shortage, the project should be suspended and results in huge losses. Previous research focuses on how financial constraints affect R&D activities (Brown et al., 2012; Almeida et al., 2013) while overlooking the interaction between real asset liquidity and financial constraints on innovation. When a firm is financially constrained, an increase in real asset liquidity provides it with an additional source of funding and mitigates the degree of financial constraints (Almeida and Campello, 2007). We predict that a more financially-constrained firm would benefit more from this funding improvement. With this rationale, funding improvement would accelerate innovation progress and generate more incremental R&D outputs. Thus, we predict that higher financial constraints would strengthen the positive relation between real asset liquidity and innovation.

The most precise classification of firm's financial constrains is to estimate the wedge between the internal and external costs of funds. A firm is classified as highly constrained if the cost of external funds is much higher than that of internal funds (Kaplan and Zingles, 1997). To capture the financial constraint, we follow Edwards et.al. (2016) and Lyandres and Palazzo (2016) employ three firm-specific proxies: △*KZ Rank;* △*Z-score* Rank; and Without *Dividend payment Dummy* (see). △*KZ Rank* is used to capture the change in investment-related financial constraint while △*Z-score Rank* is intended to capture the financial constraint generated from financial distress. The constructed process for △*KZ Rank* and △*Z-score Rank* could be listed as four steps. First, we calculate KZ index and Z-score based on Kaplan and Zingles (1997) and Alman (1968). KZ index is intuitively appealing, independent of a variety of theorem assumptions, and is composed of five parts: cash flow, Tobin's Q, leverage, dividend, and cash holding. All variables are collected from Compustat and normalized by capital expenditure. KZ index are measured as following:

$$KZ_{i,t} = -1.002 \times \frac{CF_{i,t}}{K_{i,t-1}} + 0.283 \times Tobin's\ Q_{i,t} + 3.139 \times DebtCapital_{i,t}$$

$$-39.368 \times \frac{Div_{i,t}}{K_{i,t-1}} - 1.315 \times \frac{Cash_{\ i,t}}{K_{i,t-1}} \quad (2)$$

where, *CF* is identified as cash flow (Item *IB* +Item *DP*). T*obin' Q* is calculated as ratio of market value to book value of assets ((Item *AT*+ Item *PRCC_F*×Item *CSHO*−Item *CEQ*−Item *TXDB*)/ Item *AT*). *DebtCapital* is measured by the ratio of total debt to total capital ((Item *DLTT*+ Item *DLC*)/(Item *DLTT*+ Item *DLC*+ Item *SEQ*)). *DIV* is calculated as cash dividends during the year (Item *DVC*+ Item *DVP*). *Cash* is measured as cash holdings (Item *CHE*). Finally, we scale *CF* (e.g., Cash flow), *Div* (e.g., Dividend), and *Cash* (e.g., Cash holdings) by capital expenditure (Item PPENT). By construction, KZ index is higher for more financially-constrained firms.

Altman's *Z*-score is a widely used measure for firm's failure. Edwards, Schwab, and Shevlin (2016) point out that the financial distress is the main factor underlying financial constraint. We use Altman's *Z*-score to proxy for the level of financial constraint whereas Altman's *Z*-score is measured using equation (3):

$$Z - score_{i,t} = -1 \times [3.3 \times \frac{EBIT_{i,t}}{AT_{i,t}} + 1.2 \times \frac{WP_{i,t}}{AT_{i,t}} + \frac{Sale_{i,t}}{AT_{i,t}} + 1.4 \times \frac{RE_{i,t}}{AT_{i,t}} + 0.6 \times \frac{MV_{i,t}}{LT_{i,t}}] \quad (3)$$

where, *EBIT* is identified as earnings before interest and taxes (Item *PI* +Item *XINT*). *WP* is calculated measured by working capital (Item *WCAP*). *Sale* is measured by firm's sale (Item *SALE*). *RE* is retained Earnings (Item *RE*). *MV* is measured as market value equity (Item *CHSO*×Item *PRCC_F*). *LT* is measured by liability (Item *LT*). Finally, earnings before interest and taxes, working capital, sale, retained Earnings, and market value equity are normalized by total assets (Item *AT*). By construction, Z-score index is higher for more financially-constrained firms.

Next, after we construct *KZ index* and *Z-score*, we calculate △*KZ index* and △*Z-score* from year t-1 to year t. Third, we rank all the firms and sort them into decile groups in each year over the △*KZ index* and △*Z-score*. Lastly, we assign a score to each group from highest △*KZ index* (△*Z-score*) to lowest △*KZ index* (△Z-score).[9] For example, a firm receives a score of 9 (0) if it belongs to the top (bottom) 10% of firms in a given year. The higher value presents the firm becomes financially constrained from year t-1 to year t.

Panel A of Table 6 reports whether the positive effect of real asset liquidity on innovation is enhanced when a firm is more financially constrained. We use △*KZ Rank* as proxy variable for financial constraint and present the regression results with clustered standard error by firm and year. Model (1) employs Ln (1+ *R&D expenditure*) as the dependent variable and models (2) to (4) use Ln (1+ *Patent counts*), Ln (1+ *ACWCP1*), and Ln (1+ *ACWCP2)* as dependent variables separately. The results show that coefficients of the interaction term, *AL index**△*KZ Rank,* are significantly positive. Taking innovation outputs as an example (e.g., Ln (1+ *Patent counts*), Ln (1+ *ACWCP1*), and Ln (1+ *ACWCP2*)), we find that the coefficients on the interaction term are 0.0685, 0.1029, and 0.08, respectively. The results support the argument made by Kaplan and Zingales (1997) and Cleary (1999) that the correlation between investment-cash flow sensitivities and the level of financial constraint is positive. Overall, our results support our prediction that financial constraints

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[9] Because the distribution of the underlying constraint measure is highly skewed, Edwards, Schwab, and Shelin (2016) propose the decile rank method could fix this problem.

enhance the positive impact of real asset liquidity on innovations.

[Insert Table 6]

Panel B of Table 6 alternatively uses *△Z-score Rank* to proxy the financially constrained firms. The results are consistent with the results of the *△KZ Rank* and the positive association between real asset liquidity and innovation stronger for firms with a significant financial constraint. Taking Ln (1+*ACWCP1*) as an example, the coefficients of the interaction terms, *AL Index** *△Z-score Rank* is 0.0712 at the 1% significance level.

The third proxy for financial constraint is without dividend payment dummy (*WODiv dummy*). When a firm pays dividend or repurchase stocks in a given year, it suggests the firm has abundant internal capital to do so and thus has less financial constraint. (Lyandres and Palazzo, 2016; Cleary, 1999). Therefore, firms are classified as unconstrained firms if they pay dividend or repurchase shares. We use a dummy variable, *WODiv dummy*, which is assigned to 0 if the dividend payment is not 0 (i.e.: Item *DV*>0) or repurchased share is not 0 (i.e.: Item PRSTKL>0), and *WODiv dummy* is assigned to 1, otherwise. When *WODiv dummy* is equal to 1, it indicates the firm has more financial constraint; similarly, when it is equal to 0, the firm has less financial constraint.

The results in Panel C of Table 6, using *WODiv dummy*, are consistent with the previous results in Panels A and B. The positive relationships between *AL index* and both of innovation inputs and innovation output are stronger when firms tend to no pay dividend. Taking *ACWCP1* as an example, the coefficient of the interaction terms, *AL index* * *WODiv dummy*, is 0.8175 at the 1% significance level. This again confirms that firm's financial constraints enhance the positive impact of real asset liquidity on innovations even as we use other measures of financial constraint. The results also support Garriga et.al. (2013) that financial constraints enhance a firm's innovative performance.

4.2. Product-Market Competition

In this section we investigate how product-market competition affects the relation between real asset liquidity and innovation. Innovation may effectively differentiate products within firms and generate an escape-the-competition effect (Aghion et al., 2001, 2005), which indicates that firms are likely to invest more within a competitive industry than a monopolistic industry via the so-called replacement effect (Tirole, 1988). Gu (2016) and Aghion et al. (2013) suggest that firms within competitive industries push managers to actively invest in R&D and participate in innovation races with rivals. Furthermore, if a firm could gain access to financing at a lower cost, then a competitive product market would induce it to invest more and results in a better performance on innovation output.

We utilize Herfindahl-Hirschman Index (*HHI*), number of rival firms (*NRivFirm*), and financial slack of peer firms (*FSRivFirm*) suggested by Valta (2012) as proxies for product-market competition. HHI is identified as the *negative* aggregation of the squared market share at the three-digit SIC industry level, where market share is measured by sales of firms. The higher of this value indicates the higher intensity of product-market competition. The second measure, *NRivFirm* is defined as the number of firms with debt ratings in the same industry (Shleifer and Vishny, 1992; Ortiz-Molina and Phillips, 2014). The third measure, *FSRivFirm*, is the negative average book leverage net of cash of potential buyers in the same industry (see Valta, 2012). Following Ortiz-Molina and Phillips (2014), *NRivFirm* and *FSRivFirm* are standardized to avoid the sample bias and skewness. The higher of these three variables means more intense product-market competition..

Panel A of Table 7 reports the results of using the HHI for product-market competition. We take the logarithm of one plus R&D expenditure as the dependent variable and apply a panel regression in model (1). The control variables are the same as those in Table 3. We demonstrate that the coefficients on the interaction term, *AL index* HHI*, are positive and significant. In models (2) to (4), we introduce Ln (1+ *patent counts*), Ln (1+ *ACWCP1*), and Ln (1+ *ACWCP2*), respectively, as dependent variables. The coefficients of the interaction term, (*AL Index**HHI), are all significantly positive across all regression at the 1% level. These results show that product-market competition may enhance the positive effect of real asset liquidity on innovation input (e.g., R&D expenditure) and innovation output (e.g., patent counts and patent citations). This finding is consistent with our prediction and supports the argument that product-market competition induces a firm to invest more and get better performance on innovation output (Thakor and Lo, 2015).

In a Panel B and C, we employ the widely-used number of rival firms (*NRivFirm*), and financial slack of peer firms (*FSRivFirm*) as a proxy for product-market competition in Panels B and C, respectively. Similar to the results in Panel A, all coefficients of the interaction terms, *AL Index* NRivFirm* and *AL Index* FSRivFirm*, are mostly significantly positive at the 1% level. These results support the replacement-effect hypothesis that product-market competition encourages a firm to aggressively invest in innovative activity, confirming the escape-the-competition effect (Aghion et al., 2001; Aghion et al., 2005).

[Insert Table 7]

5. Robustness Tests

5.1. The Endogeneity of Real Asset Liquidity

5.1.1 Instrumental Variable Approach

The endogeneity of real asset liquidity has always been a major concern in studies of the economic consequence of corporate innovation. In this section, our analysis turn to inferences based on instrumental variables (IV) approaches and estimate a two-stage least squares (2SLS) regression treating real asset liquidity as endogenous to modeling the relation between a firm's innovation and its real asset liquidity. Following Campello and Giambona (2013), we use two instrumental variables for real asset liquidity: *IndResale and IndTan*.

Our first instrument considers the market demand for machinery and equipment and the liquidity of machinery and equipment within the industry where the firm operates. If the equipment can be easily fetched in the secondary market, it needs not to be built by the firm and can be purchased as used goods and integrated in the firm's production process at a lower user cost (Gavazza, 2011). Therefore, firms operating their equipment in industries with an active secondary market are more likely to take those assets at a lower cost (Almeida and Campello, 2007). Following Schlingemann et al. (2002), we use the ratios of sales of PP&E to the sum of sales of PP&E and capital expenditures, at 2-digit SIC industry-year level, (Item *SPPE* /(Item *SPPE* + Item CAPX) in COMPUSTAT) as a proxy for the liquidity of machinery and equipment in the industry a firm operates (Sibilkov, 2009). This proxy is denoted by *IndResale*.

The second instrument is based on the argument that a firm's financial and real decisions are linked to the product-market dynamics (e.g., Maksimovic and Zechner, 1991; Williams, 1995).[10] To capture the industry dynamics, we use the average of Land&Building, Machinery&Equipment, and OtherTangibles at 2-digit SIC industry-year level, and we denote this proxy by *IndTan.* In this definition, *Land&Building* is measured by the ratio of net book value of land and building to the book value of total asset, at 2-digit SIC industry-year level ((Item *PPENLI*+ Item *PPENB*)/ Item *AT* in COMPUSTAT). *Machinery&Equipment* is measured by the ratio of net book value of machinery and equipment to the book value of total asset, at 2-digit SIC industry-year level ((Item *PPENME*/*AT*) in COMPUSTAT). *OtherTangibles* is measured by the ratio of plant and equipment in progress and miscellaneous tangible assets to the book value of total assets, at 2-digit SIC industry-year level ((Item *PPENC*+ Item *PPENO*)/ Item *AT*) in COMPUSTAT).

Results based on the 2SLS regression are reported in Table 8. Models (1) through (4) separately report the innovative input (Ln (1+*R&D expenditure*)) and innovative output (Ln (1+*Patent counts*), Ln (1+*ACWCP1*), Ln (1+*ACWCP2*)). We show that after explicitly controlling for possible endogeneity, the coefficients for AL index remain positive and significant at the 1% level. Overall, the results reported in Table 8 suggest a positive relation between real asset liquidity

[10]The collective decisions made by a firm's industry rivals reflect these asset characteristics, yet they are exogenous to the individual firm's choice set. Evidence of these links is presented by MacKay and Phillips (2005) and Campello (2006).

and corporate innovation is not likely driven by endogeneity bias.[11]

[Insert Table 8]

5.1.2 Difference-in-Difference Approach

In this subsection, we use the DiD approach to reexamine the impact of real asset-liquidity on firm innovation. Following Campello and Giambona (2013), we focus on the year of 1992, in which the sale of military bases and supply of real estate are increased by the U.S. government following the end of the cold war. After the Iron Curtain surrendered, the U.S. government disarmed the military on a large scale and disposed the military installation across the country. From this disposition, the supply of land and building dramatically increases more than 100,000 acres for redevelopment into office parks and industrial zones (Murphy, 2003). The shock to the supply of corporate-type assets, generated from massive sale of superfluous assets at the end of the cold war, leads to a reduction in the collateral value and real asset liquidity, and would affect corporate innovation. Therefore, we take this event as an exogenous event for real asset liquidity shock and use difference-in-difference approach to examine its impact on innovation.

The D-i-D model specification is outlined in following steps. First, the methodology is based on the differences in response of large and small firms to supply-side shock. Specifically, smaller firms are more negatively responsive to shock on the reduction of collateral value than are larger firms, and therefore we take small firms as treated firms and large firms as untreated firms. Our identification strategy compares the innovation input and output of smaller firms to that of larger firms after the shock of supply from end of cold war.

Second, in order to expel other sources of heterogeneity on the differences between treated firms and untreated firms. We employ the D-i-D matching estimator approach. We match treatment

[11] We report Cragg-Donald Wald statistics in the last row of Table 8. These statistics are greater than the 10% critical value by 19.93 derived from Atock-Yogo's test. The results suggest that the instrumental variables are not weak. We cannot reject the null hypothesis that our instruments are uncorrelated with error terms, implying our model is well-specified at a conventional level of significant.

firms (the firm's assets are below the median of all sample given the year of 1990) with a subsample of untreated firms (the firm's assets are beyond the median of all sample given the year of 1990) that are identified as the closest matches in terms of sale, profitability, Tobin's Q and leverage. Our sample consists of 328 firms to create the matching sample in this step. We assume the cold war ended in fiscal-year 1991, therefore, we calculate the variables differences from 1991 to 1992. We explain the negative impact of the supply of land on innovation for two reasons. First, the increase in land supply may decrease the firm's collateral value. Second, it might obstruct the firm's access to external resources. We expect that the mean innovation difference between treated firms and untreated firms would be larger and the value in column (3) would be significantly negative after the end of Cold War if the shock of supply sharply damages the collateral value.

The results of D-i-D matching estimation are reported in Table 9. Panel A of the Table 9 report the D-i-D estimation results for innovation inputs and outputs. The mean estimate of *ΔLn (1+ R&D expenditure)* for treated-untreated firms in column (3) is 0.005 and not significant, while the means estimate of innovation outputs (*ΔLn (1+ Patent counts), ΔLn (1+ ACWCP1), ΔLn (1+ ACWCP2)*) are negative and most of them are statistically significant. Overall, the results in Table 9 indicate that the local supply shock to real estate results in lower real assets liquidity, which is in turn to decrease a firm's innovation. This result suggests that our D-i-D analysis confirms that real asset liquidity positively affects corporate innovation.

The panel B of Table 9 reports the change in innovation in a regression analysis. We retain firm-year observation for treated firm and untreated firm from pre-cold war periods to post-cold war period.

$$y_{i,t} = \beta_1 TREAT * POSTWAR + \beta_2 * TREAT + \beta_3 * POSTWAR + \boldsymbol{\beta}\mathbf{X}_{i,t} + \mu_i + \upsilon_t + \varepsilon_{i,t} \quad (4)$$

Where $y_{i,t}$ is the inputs or outputs of innovation, such as Ln (1+*R&D expenditure*), Ln (1+*Patent counts*), Ln (1+*ACWCP1*), Ln (1+ *ACWCP2*); $TREAT$ is a dummy variable that is one if the value of firm's assets is lower than the median of all sample in the year of 1990, and 0 otherwise. We define 1991 as the end of Cold War; therefore, we define a dummy variable POST, which equals to one in the year of 1992 and zero in the year 1990-1991; μ_i is the industry-fixed effect; υ_t is the time-fixed effect; $\varepsilon_{i,t}$ is the error term; and $\mathbf{X}_{i,t}$ is the vector of control variables as the same as in the Table 3. In this specification, we expect the sign of $TREAT * POSTWAR$ to be negative and significant.

We report the results of estimating equation (4) in Panel B of Table 9. The coefficients of *TREAT*POSTWAR* are negative and significant at one percent level for innovation output. The results suggest that treated firms (small firms) generate less patents and citations than for untreated firms (big firms) after the end of the cold war, which is consistent with our hypothesis that a firm's real asset liquidity positively affects its innovations.

5.2 Reconciliation with the Competing Perspective

On the basis of the empirical findings by Gopalan et al. (2012) and Fang et al. (2014), an opposing view emerges: real asset liquidity may impede corporate innovation. This perspective represents an interesting contrast with the overall empirical findings we have compiled so far in support of the first view on a positive relation between the two. Naturally, a careful reevaluation of this opposing perspective is in order. Because Gopalan et al. (2012) and Almeida and Campello (2007) construct the firm-level measures of total asset liquidity from financial statements, we also introduce the same set of three measures based on firm-level measure and alternatively employ two measures relied on "market-equilibrium" real asset liquidity measures of Shleifer and Vishny (1992).

The assets in a firm's balance sheet are assigned a liquidity score between 0 and 1 based on their degree of liquidity, and the total asset liquidity measure is a weighted average of the liquidity scores times the corresponding assets in the balance sheet. This set of measures may belong to three categories. The first measure of asset liquidity, *WAL1*, captures the information that all assets except for cash and equivalents are illiquid. A score of 1 is assigned to cash and equivalents and a score of 0 to all other assets. We then calculate this weighted measure by normalizing it to the lagged value of total assets. The measure for firm *i* in year *t* is:

$$WAL1_{i,t} = \frac{Cash\ \&\ Eq._{i,t}}{Total\ Asset_{i,t-1}} \times 1 + \frac{Other\ Assets_{i,t}}{Total\ Asset_{i,t-1}} \times 0$$

The second measure, *WAL2*, includes cash and equivalents and non-cash current assets. Because non-cash current assets are semi-liquid, they are assigned a score of 0.5. This measure captures how quickly assets are converted to cash at a low cost, and this second measure can be defined as:

$$WAL2_{i,t} = \frac{Cash\ \&\ Eq._{i,t}}{Total\ Asset_{i,t-1}} \times 1 + \frac{Noncash\ CA_{i,t}}{Total\ Asset_{i,t-1}} \times 0.5 + \frac{Other\ Assets_{i,t}}{Total\ Asset_{i,t-1}} \times 0$$

To construct the third measure (*WAL3*), non-cash current assets are divided into tangible and intangible assets. Based on the level of liquidity, the variables of tangible assets, non-cash current assets, and cash are assigned a score of 0.5, 0.75, and 1, respectively. This third measure is defined as:

$$WAL3_{i,t} = \frac{Cash\ \&\ Eq._{i,t}}{Total\ Asset_{i,t-1}} \times 1 + \frac{Noncash\ CA_{i,t}}{Total\ Asset_{i,t-1}} \times 0.75 + \frac{Tangible\ Fixed\ Assets_{i,t}}{Total\ Asset_{i,t-1}} \times 0.5 + \frac{Other\ Assets_{i,t}}{Total\ Asset_{i,t-1}} \times 0$$

Panel A in Table 10 reports the summary statistics on three firm-level measures and two industry-level measures of total asset liquidity. The mean of *WAL1*, *WAL2* and *WAL3* are respectively 0.158, 0.366 and 0.625, which are similar to the reports of Gopalan et al. (2012) and Almeida and Campello (2007) on these measures (i.e., 0.142, 0.322, and 0.664,). Panel B in Table 10 presents the matrix of the Spearman correlation coefficients, demonstrating the correlations between the six total asset liquidity measures (e.g., *WAL1*, *WAL2*, *WAL3*) and innovation. The firm-level measures of total asset liquidity are significantly and negatively correlated with the Ln (1+*R&D expenditure*), Ln (1+*patent counts*), Ln (1+*ACWCP1*), and Ln (1+*ACWCP2*).

Panel C of Table 10 shows the regression results. The main firm-level explanatory variables are *WAL1*, *WAL2* and *WAL3*. All control variables are similar to Table 3. We find that all variables have a positive and statistically significant impact on R&D expenditure. We take *WAL1* as an example. The regression coefficient of *AL index* on Ln (1+*R&D expenditure*) is approximately 2.188. The product of this ratio (2.188) and the mean Ln (1+*R&D expenditure*) (2.478) from Table 1 is 5.421. This shows that a one-unit increase in asset liquidity measured by *WAL1* enhances R&D expenditure by 5.421. In sum, from the results in Panel C of Table 10, we observe that firms with higher asset liquidity measured by a firm's balance sheet increase innovation inputs and outputs.

[Insert Table 10]

Gopalan et al. (2012) empirically find that asset liquidity measures based on balance-sheet information positively and economically affect stock liquidity. On the other hand, Fang et al. (2014) note that stock liquidity impedes corporate innovation through increased exposure to hostile takeovers and the higher presence of institutional investors who do not actively gather information about firm fundamentals or conduct monitoring. Combined with the above two streams of research, stock liquidity may play an intermediary role in affecting the relation between asset liquidity and innovation. To further rule out this possibility, we use a two-step regression approach to reinforce our findings compiled so far.

We use the square root version of Amihud's (2002) measure to proxy for stock liquidity. We first regress asset liquidity measured by *WAL1*, *WAL2*, and *WAL3* on stock liquidity and obtain the regression residuals (*Res. WAL1*, *Res. WAL2*, and *Res. WAL3*). These residuals are correlated with asset liquidity, but are orthogonal to stock liquidity. In the second stage, we regress corporate innovations on asset liquidity residuals and other control variables for corporate innovations. By doing so, we can test whether asset liquidity affects corporate innovations through the stock liquidity channel. In Tables 11, we find that the positive association between asset liquidity residuals and innovations still holds in both innovation input and output. This finding rules out the channel wherein the firm's propensity for innovation is affected by asset liquidity through stock liquidity and confirms that asset liquidity indeed plays a dominant role in motivating innovation.

[Insert Tables 11]

6. Conclusion

This paper empirically examines the effect of real asset liquidity on corporate innovations. By employing four widely-used real asset liquidity measures (the number of rival firms, the financial slack of a rival firm, within-industry M&A value, and out-of-industry M&A value), we construct a real asset liquidity index. In addition, we measure innovation activities from innovation inputs *(Ln (1+R&D expenditure))* and innovation outputs *(Ln (1+patent), Ln (1+ACWCP1), Ln (1+ACWCP2))*. We find that real asset liquidity enhances firm innovation, which supports the perspective built on the cost-of-capital hypothesis. Furthermore, our empirical results are robust using alternative accounting-based asset liquidity measures as in Gopalan et al. (2012) and not affected by endogeneity bias.

We further investigate the impact of financial constraint and product-market competition on the association between real asset liquidity and corporate innovations. More liquid real assets facilitate innovations; however, this facilitation is weakened by higher financial constraints while enhanced by intense product-market competition. In sum, our research confirms that a firm's liquid real asset effectively provides a financing channel to enhance innovation. To understand a firm's propensity to innovate, one may need to consider not only its managerial attributes or financial availability, but also the characteristics of its real asset. We leave this issue for future research.

Appendix: Definitions of Variables

Variable	Description
Measure of Innovation	
Ln (1+R&D expenditure)	Research and development expenditure, in log.
Ln (1+Patent counts)	The counts of a firm's patents, in log.
Ln (1+ACWCP1)	Each patent's citations are multiplied by the weighting index of Hall, Jaffe, and Trajtenberg (2001, 2005), which is contained in the NBER patent database. Next, we aggregate the weighted citations across all patents based on firm-applied year level, in log.
Ln (1+ACWCP2)	The patent citations of each patent are scaled by the average patent citations, which are in the same technology and year. Next, we aggregate the weighted citations across all patent based on firm-applied year level, in log.
Measure of AL Index	
AL index	$0.715 \times \text{RECT} + 0.547 \times \text{INV} + 0.535 \times \text{CAP} + \text{Cash}$ Where RECT is measured by total receivables. INV is identified as firm's inventory. CAP is calculated as property, plant, and equipment. Cash is cash holdings.
Firm Characteristics	
Ln(Sale)	Sales, in log.
Ln(Capital/Labor)	Ratio of capital to number of labor; capital is measured by gross property, plant, and equipment (ppegt), in log.
Ln(Firm Age)	The number of years that the firm is in Compustat, in log.
ROA	Operating income before depreciation/total assets.
Sale Growth	The firm's sales this year scaled by its sales in the prior year.
Leverage	Debt/total asset, where debt is sum of long-term debt and current liability.
Tobin's Q	The ratio of market value to total assets. The market value is calculated as total assets plus market value of equity minus deferred taxes minus book value of equity.

Variable	Description (continued)
△KZ Rank	$KZ_{i,t} = -1.002 \times \frac{CF_{i,t}}{K_{i,t-1}} + 0.283 \times Tobin\acute{}s\ Q_{i,t} + 3.139 \times DebtCapital_{i,t} - 39.368 \times \frac{Div_{i,t}}{K_{i,t-1}} - 1.315 \times \frac{Cash_{\ i,t}}{K_{i,t-1}}$ We calculate △KZ by difference between KZ_t and KZ_{t-1}, then rank all the firms and sort them into ten quintile groups in each year over the △KZ and assign a score to each group from highest △KZ to lowest △KZ. Here, CF is identified as cash flow. Tobin' Q is calculated as ratio of market value to book value of assets. DebtCapital is measured by the ratio of total debt to total capital. *DIV* is calculated as cash dividends during the year. *Cash* is measured as cash holdings. Finally, we scale Cash flow, Dividend, and Cash holdings by capital expenditure.
△Z-score Rank	$Z-score_{i,t} = -1 \times \{3.3 \times \frac{\mathrm{EBIT}_{i,t}}{\mathrm{AT}_{i,t}} + 1.2 \times \frac{\mathrm{WP}_{i,t}}{\mathrm{AT}_{i,t}} + \frac{\mathrm{Sale}_{i,t}}{\mathrm{AT}_{i,t}} + 1.4 \times \frac{\mathrm{RE}_{i,t}}{\mathrm{AT}_{i,t}} + 0.6 \times \frac{\mathrm{MV}_{i,t}}{\mathrm{LT}_{i,t}}$ We calculate △Z-score by difference between Z_t and Z_{t-1}, then rank all the firms and sort them into ten quintile groups in each year over the △Z and assign a score to each group from highest △Z to lowest △Z. where, EBIT is identified as earnings before interest and taxes. WP is calculated measured by working capital. Sale is measured by firm's sale. *RE* is retained Earnings. *MV* is measured as market value equity. LT is measured by liability. Finally, earnings before interest and taxes, working capital, sale, retained Earnings, and market value equity are normalized by total assets.
Dividend Payment	Indicator variable that are assigned to one if the firm paid dividend (Item DV>0) or repurchased share (Item PRSTKL>0) in a given year, zero for otherwise.
HHI (Herfindahl Hirschman Index)	(-1) * HHI, where HHI is the aggregation of squared market share at the three-digit SIC industry level.
WAL1	$\text{Cash and Equivalents}_{i,t}/\text{Total assets}_{i,t-1}$

Variable	Description (continued)
WAL2	Cash and $\text{Equivalents}_{i,t}/\text{Total assets}_{i,t-1}$ $+0.5 \times (Noncash\ Current\ Assets_{i,t})/(Total\ assets_{i,t-1})$
WAL3	Cash and $\text{Equivalents}_{i,t}/\text{Total assets}_{i,t-1}$ $+0.75 \times (Noncash\ Current\ Assets_{i,t})/(Total\ assets_{i,t-1})$ $+0.5 \times (Tangibl\ Fixed\ Assets_{i,t})/(Total\ assets_{i,t-1})$
NRivFirm	The number of rival firms is other firms with a debt rating in the same three-digit SIC industry.
FSRivFirm	(Cash-Debt)/Book assets), where debt is long-term debt plus short-term debt.
Amihud	The square root of average annual Amihud (2002). Amihud's measure is calculated as the ratio of the absolute daily stock return to the daily trading volume.

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Table 1

Summary statistics

This table presents summary statistics for the main variables, control variables, and dependent variables. The sample period is from 1986 to 2006. The definitions of all variables are listed in the Appendix.

Variable	N	Mean	Std. Dev	25%	50%	75%
Panel A: Innovation measures						
Ln (1+R&D expenditure)	22,645	2.583	1.902	0.914	2.537	4.062
Patent counts	22,645	30.693	131.694	1.000	3.000	12.000
ACWCP1	22,645	451.800	2313.72	11.368	39.620	163.073
ACWCP2	22,645	30.845	129.873	0.982	3.337	13.107
Panel B: Real asset liquidity measure						
AL index	22,645	0.456	0.137	0.381	0.439	0.502
Panel C: Control Variables						
Ln (Sale)	22,645	5.648	2.231	4.140	5.681	7.295
Ln (K/L)	22,645	3.166	1.097	2.427	3.110	3.826
Ln(Firm age)	22,645	2.354	0.853	1.792	2.485	2.996
ROA	22,645	0.122	0.211	0.100	0.153	0.206
Ln (Sale growth)	22,645	-1.972	1.132	-2.535	-1.904	-1.306
Leverage	22,645	0.204	0.172	0.066	0.194	0.301
Tobin's Q	22,645	2.159	2.687	1.032	14.472	2.297
ΔKZ Rank	22,645	4.389	2.902	2.000	4.000	7.000
ΔZ-score Rank	22,645	4.516	2.980	2.000	5.000	7.000
Dividend dummy	22,645	0.661	0.474	0.000	1.000	1.000
HHI	22,645	-0.167	0.131	-0.204	-0.136	-0.788
NRivFirm	19,452	5.832	7.624	1.000	3.000	6.000
FSRivFirm	19,452	0.136	0.666	0.123	0.208	0.305

Table 2

Spearman correlation coefficients

This table presents the matrix of Spearman correlation coefficients, capturing the simple relations between innovation, real asset liquidity index, and firm characteristics. ***, **, and * reported below are significant at the 1%, 5%, and 10% levels, respectively. The definitions of all variables are listed in Appendix A.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) Ln (1+R&D expenditure)	1.000											
(2) Ln(1+Patent counts)	0.610***	1.000										
(3) Ln(1+ACWCP1)	0.493***	0.814***	1.000									
(4) Ln(1+ACWCP2)	0.520***	0.855***	0.952***	1.000								
(5) AL index	-0.015**	-0.073***	-0.022***	-0.040***	1.000							
(6) Ln(Sale)	0.479***	0.507***	0.365***	0.414***	-0.327***	1.000						
(7) Ln(K/L)	0.256***	0.220***	0.127***	0.143***	0.033***	0.343***	1.000					
(8) Ln(Firm age)	0.139***	0.256***	0.160***	0.185***	-0.329***	0.518***	0.182***	1.000				
(9) ROA	0.049***	0.107***	0.133***	0.122***	-0.019***	0.245***	-0.071***	0.148***	1.000			
(10) Ln(Sales growth)	-0.048***	-0.102***	-0.044***	-0.066***	0.218***	-0.333***	-0.041***	-0.397***	-0.061***	1.000		
(11) Leverage	-0.0569***	0.027***	-0.010	0.018***	-0.398***	0.266***	0.085***	0.198***	-0.136***	-0.165***	1.000	
(12) Tobin's Q	0.164***	0.027***	0.070***	0.031***	0.236***	-0.185***	0.184***	-0.197***	0.151***	0.324***	-0.385***	1.000

Table 3

Real asset liquidity (AL Index) and innovation input

This table is the regression results by panel regression with two-way clustered standard errors for firms and year, as suggested by Petersen (2009), and controls industry and year fixed effects. The dependent variable is Ln (1+R&D expenditure). The t-statistics are reported in parentheses below the coefficient. The values in parentheses are t-value. ***, **, and * reported below are significant at the 1%, 5%, and 10% levels, respectively. All variables are lagged by 1 year. The definitions of all variables are listed in Appendix A. The regression specification is shown as follows: $y_{i,t+n} = AL_{i,t}\beta_1 + \boldsymbol{X}'_{i,t}\boldsymbol{\beta} + \mu_i + \upsilon_t + \varepsilon_{i,t}$, where n equals one, two, and three.

Panel A: Innovation Output measured by Ln (1+R&D expenditure)			
	(1)	(2)	(3)
Dependent variable	Ln (1+R&D expenditure)$_{t+1}$	Ln (1+R&D expenditure)$_{t+2}$	Ln (1+R&D expenditure)$_{t+3}$
AL index	1.8930***	1.0580***	1.9603***
	(22.97)	(13.02)	(19.92)
Ln (Sale)	0.6722***	0.4931***	0.6777***
	(98.88)	(60.80)	(94.33)
Ln (K/L)	0.0801***	0.1269***	0.0312*
	(5.30)	(9.70)	(1.92)
Ln(Firm age)	-0.1369***	-0.0132	-0.1763***
	(-10.83)	(-1.08)	(-12.80)
ROA	-1.2227***	-0.9060***	-1.0653***
	(-10.80)	(-5.92)	(-7.55)
Ln (Sale growth)	0.0577***	0.0604***	0.0727***
	(6.47)	(7.10)	(7.33)
Leverage	-0.6474***	-0.5795***	-0.6921***
	(-9.41)	(-8.12)	(-8.79)
Tobin's Q	0.0500***	0.0458***	0.0753***
	(9.38)	(6.37)	(9.90)
Control Variable	Y	Y	Y
Industry FE &Year FE	Y	Y	Y
N	22,645	21,705	20,783
Adj. R^2	0.84	0.84	0.83

Table 4
Real asset liquidity (AL Index) and innovation output

This table reports the regression results, controlling for the industry and year fixed effects. The dependent variables are Ln (1+patent counts), Ln (1+ACWCP1), and Ln (1+ACWCP2) in Panel A, Panel B, and Panel C. The control variables are the same as Table 3. The values in parentheses are t-value. ***, **, and * are significant at the 1%, 5%, and 10% levels, respectively. The definitions of all variables are listed in Appendix A

Panel A: Innovation measured by Ln(1+Patent counts)

	(1)	(2)	(3)
Dependent	$Ln(1+Patent\ counts)_{t+1}$	$Ln(1+Patent\ counts)_{t+2}$	$Ln(1+Patent\ counts)_{t+3}$
AL index	0.9551***	0.9390***	1.0468***
	(14.57)	(13.83)	(13.55)
Control Variable	Y	Y	Y
Industry FE &Year	Y	Y	Y
N	22,645	21,705	20,783
Adj. R^2	0.82	0.83	0.83

Panel B: Innovation measured by Ln(1+ACWCP1)

	(1)	(2)	(3)
Dependent variable	$Ln(1+ACWCP1)_{t+1}$	$Ln(1+ACWCP1)_{t+2}$	$Ln(1+ACWCP1)_{t+3}$
AL index	1.2638***	1.2478***	1.2418***
	(11.87)	(11.24)	(10.14)
Control Variable	Y	Y	Y
Industry FE &Year	Y	Y	Y
N	22,645	21,705	20,783
Adj. R^2	0.87	0.87	0.87

Panel C: Innovation measured by Ln(1+ACWCP2)

	(1)	(2)	(3)
Dependent variable	$Ln(1+ACWCP2)_{t+1}$	$Ln(1+ACWCP2)_{t+2}$	$Ln(1+ACWCP2)_{t+3}$
AL index	1.0447***	1.0580***	1.0867***
	(13.39)	(13.02)	(11.86)
Control Variable	Y	Y	Y
Industry FE &Year	Y	Y	Y
N	22,645	21,705	20,783
Adj. R^2	0.77	0.77	0.77

Table 5 Omitted Variables

This table is the regression results by panel regression with two-way clustered standard errors for firms and year, as suggested by Petersen (2009), and control M&A activities, industry-level R&D growth, CEOs compensation, and CEO characteristics. CEOs compensation include CEO cash compensation, CEO delta and CEO vega. CEO characteristics include CEO tenure and CEO age. The dependent variables are Ln (1+R&D expenditure), Ln (1+patent counts), Ln (1+ACWCP1), and Ln (1+ACWCP2). The values in parentheses are t-value. ***, **, and * reported below are significant at the 1%, 5%, and 10% levels, respectively. The definitions of all variables are listed in Appendix A.

	(1)	(2)	(3)	(4)
Dependent variable	Ln (1+R&D expenditure)$_{t+1}$	Ln(1+Patent counts)$_{t+1}$	Ln(1+ACWCP1)$_{t+1}$	Ln(1+ACWCP2)$_{t+1}$
AL index	1.0519***	0.7875***	0.8090**	0.6772***
	(4.44)	(3.96)	(2.52)	(2.71)
Ln (1+#M&A activity)	0.0131	-0.1260	-0.1088	-0.0497
	(0.12)	(-1.47)	(-0.78)	(-0.46)
Ind. R&D growth	0.2212*	0.0273	-0.0572	-0.0179
	(1.93)	(0.40)	(-0.54)	(-0.23)
Ln (CEO tenure)	-0.1525***	-0.0845***	-0.1483***	-0.1041***
	(-3.96)	(-2.79)	(-3.09)	(-2.82)
Ln (CEO age)	-0.1099	-0.4734***	-0.3019	-0.4349***
	(-0.79)	(-3.55)	(-1.61)	(-2.92)
Ln (Cash Compensation)	0.0701*	0.0457**	0.0320	0.0367
	(1.66)	(2.01)	(0.76)	(1.31)
CEO delta	-0.0003	0.1232***	0.1574***	0.1252***
	(-0.01)	(4.64)	(3.67)	(3.92)
CEO vega	0.1950***	0.0283	0.0849***	0.0419*
	(6.53)	(1.48)	(2.69)	(1.80)
Other Control variables	Y	Y	Y	Y
Industry FE & Year FE	Y	Y	Y	Y
N	2,608	2,608	2,608	2,608
Adj. R^2	0.90	0.87	0.87	0.80

Table 6

The effect of financial constraint on the relation between real asset liquidity and innovation

This table investigates the effect of asset liquidity on innovation in the presence of financial constraint. We measure financial constraint by using the ∆KZ Rank, ∆Z-score Rank, WODiv dummy. The dependent variables are Ln (1+R&D expenditure), Ln (1+Patent counts), Ln (1+ACWCP1), and Ln (1+ACWCP2). The regression of the model is $y_{i,t+1} = AL_{i,t}\beta_1 + \boldsymbol{X}'_{i,t}\boldsymbol{\beta} + \mu_i + \upsilon_t + \varepsilon_{i,t}$, which is a panel regression with two-way clustered standard error for firm and year, as suggested by Petersen (2009), and includes industry and year fixed effects. The control variables are Ln (Sale), Ln (K/L), Ln (Firm age), ROA, Ln (Sales growth), Leverage, and Tobin's Q. The t-statistics are reported in parentheses below the coefficient. ***, **, and * reported below are significant at the 1%, 5%, and 10% level, respectively. The definitions of all variables are listed in Appendix.

Panel A: ∆KZ Rank

	(1)	(2)	(3)	(4)
Dependent variable	Ln (1+R&D expenditure) $_{t+1}$	Ln(1+Patent counts) $_{t+1}$	Ln(1+ACWCP1) $_{t+1}$	Ln(1+ACWCP2) $_{t+1}$
AL index	2.0767***	1.2264***	1.6807***	1.3651***
	(18.60)	(14.34)	(11.76)	(13.22)
AL index * ∆KZ Rank	0.0457**	0.0685***	0.1029***	0.0800***
	(2.57)	(4.96)	(4.40)	(4.74)
∆KZ Rank	-0.0215**	-0.0344***	-0.0469***	-0.0383***
	(-2.20)	(-4.69)	(-3.89)	(-4.36)
Control variables	Y	Y	Y	Y
Industry FE & Year FE	Y	Y	Y	Y
N	22,645	22,645	22,645	22,645
Adj. R^2	0.84	0.82	0.87	0.76

Panel B: ∆Z-score Rank

	(1)	(2)	(3)	(4)
Dependent variable	Ln (1+R&D expenditure) $_{t+1}$	Ln(1+Patent counts) $_{t+1}$	Ln(1+ACWCP1) $_{t+1}$	Ln(1+ACWCP2) $_{t+1}$
AL index	2.0295***	1.1415***	1.5298***	1.2050***
	(18.60)	(13.49)	(10.94)	(11.76)
AL index *∆Z-score Rank	0.0368**	0.0497***	0.0712***	0.0429**
	(2.10)	(-3.51)	(2.98)	(2.48)
∆Z-score Rank	-0.0049	-0.0178**	-0.0201*	-0.0127
	(-0.52)	(-2.41)	(-1.66)	(-1.43)
Control variables	Y	Y	Y	Y
Industry FE & Year	Y	Y	Y	Y
N	22,645	22,645	22,645	22,645
Adj. R^2	0.84	0.83	0.87	0.76

Panel C: WODiv dummy				
	(1)	(2)	(3)	(4)
Dependent variable	Ln (1+R&D expenditure) $_{t+1}$	Ln(1+Patent counts) $_{t+1}$	Ln(1+ACWCP1) $_{t+1}$	Ln(1+ACWCP2) $_{t+1}$
AL index	2.1250***	1.1417***	1.5291***	1.2453***
	(21.97)	(14.55)	(11.75)	(13.14)
AL index * WODiv Dummy	0.7671***	0.5355***	0.8175***	0.5972***
	(5.32)	(4.70)	(4.44)	(4.39)
WODiv dummy	-0.0219	-0.1434***	-0.1387	-0.1276**
	(-0.31)	(-2.64)	(-1.59)	(-1.98)
Control variables	Y	Y	Y	Y
Industry FE & Year	Y	Y	Y	Y
N	22,624	22,624	22,624	22,624
Adj. R2	0.84	0.82	0.87	0.76

Table 7

The effect of product-market competition on the relation between real asset liquidity and innovation

This table investigates the effect of asset liquidity on innovation in the presence of product-market competition. We use the HHI, NRivFirm (#of rival firm), and FSRivFirm (Financial slack) to proxy for product-market competition. FSRivFirm is the average of the spread of cash holding and leverage, divided by total assets at three-digit SIC code industry level. #of rival firm. NRivFirm and FSRivFirm are standardized to mean by zero and standard deviation by one. The dependent variables are Ln (1+R&D expenditure), Ln (1+Patent counts), Ln (1+ACWCP1), and Ln (1+ACWCP2). The regression of model is $y_{i,t+1} = AL_{i,t}\beta_1 + \boldsymbol{X}'_{i,t}\boldsymbol{\beta} + \mu_i + \upsilon_t + \varepsilon_{i,t}$, which is the panel regression with two-way clustered standard error for firm and year, as suggested by Petersen (2009), and includes industry and year fixed effects. The control variables are Ln (Sale), Ln (K/L), Ln (Firm age), ROA, Ln (Sales growth), Leverage, and Tobin's Q. ***, **, and * reported below are significant at the 1%, 5%, and 10% levels, respectively. The definitions of all variables are listed in Appendix.

Panel A: HHI

	(1)	(2)	(3)	(4)
Dependent variable	Ln (1+R&D expenditure) $_{t+1}$	Ln(1+Patent counts) $_{t+1}$	Ln(1+ACWCP1) $_{t+1}$	Ln(1+ACWCP2) $_{t+1}$
AL index	2.1186***	1.2278***	1.6649***	1.3605***
	(19.04)	(14.46)	(11.80)	(13.12)
AL index * HHI	2.0987***	2.1412***	3.3702***	2.5552***
	(3.20)	(4.69)	(4.52)	(4.67)
HHI	-0.5344*	-1.0829***	-1.3482***	-1.1693***
	(-1.81)	(-5.43)	(-4.22)	(-4.90)
Control variables	Y	Y	Y	Y
Industry FE & Year FE	Y	Y	Y	Y
N	22,645	22,645	22,645	22,645
Adj. R^2	0.84	0.83	0.87	0.76

Panel B: NRivFirm

	(1)	(2)	(3)	(4)
Dependent variable	Ln (1+R&D expenditure) $_{t+1}$	Ln(1+Patent counts) $_{t+1}$	Ln(1+ACWCP1) $_{t+1}$	Ln(1+ACWCP2) $_{t+1}$
AL index	1.5304***	0.7856***	1.2218***	0.8521***
	(15.80)	(9.95)	(9.48)	(9.04)
AL index * NRivFirm	0.6464***	0.3241***	0.0932	0.2058**
	(7.98)	(4.79)	(0.83)	(2.50)
NRivFirm	-0.1534***	-0.1437***	-0.0445	-0.0761*
	(-3.08)	(-3.72)	(-0.72)	(-1.65)
Control variables	Y	Y	Y	Y
Industry FE & Year FE	Y	Y	Y	Y

N	11,525	11,525	11,525	11,525
Adj. R2	0.86	0.82	0.86	0.74

Panel C: FSRivFirm				
	(1)	(2)	(3)	(4)
Dependent variable	Ln (1+R&D expenditure)$_{t+1}$	Ln(1+Patent counts)$_{t+1}$	Ln(1+ACWCP1)$_{t+1}$	Ln(1+ACWCP2)$_{t+1}$
AL index	1.7265***	0.8046***	1.1456***	0.8187***
	(18.27)	(10.20)	(9.01)	(8.73)
AL index * FSRivFirm	0.0107	0.3655***	0.7050***	0.6247***
	(0.09)	(3.15)	(4.44)	(4.71)
FSRivFirm	-0.0714	-0.1925***	-0.3173***	-0.2933***
	(-1.07)	(-3.24)	(-4.41)	(-4.72)
Control variables	Y	Y	Y	Y
Industry FE & Year FE	Y	Y	Y	Y
N	11,525	11,525	11,525	11,525
Adj. R2	0.86	0.82	0.86	0.75

Table 8

IV robustness tests for the endogeneity of real asset liquidity

This table reports the two-stage least square (2SLS) regression results from robustness checks for the endogeneity of real asset liquidity. The dependent variable is Ln (1+R&D expenditure), Ln (1+Patent counts), Ln (1+ACWCP1), and Ln (1+ACWCP2) from model (1) to model (4). The instrumental variables are IndResale and IndTan. The control variables are Ln (Sale), Ln (K/L), Ln (Firm age), ROA, Ln (Sales growth), Leverage, and Tobin's Q. The t-statistics are reported in parentheses below the coefficient. ***, **, and * reported below are significant at the 1%, 5%, and 10% levels, respectively. The definitions of all variables are listed in Appendix.

	(1)	(2)	(3)	(4)
Dependent variable	Ln (1+R&D expenditure)$_{t+1}$	Ln(1+Patent counts)$_{t+1}$	Ln(1+ACWCP1)$_{t+1}$	Ln(1+ACWCP2)$_{t+1}$
AL index	22.85***	10.64***	26.61***	14.55***
	(3.35)	(2.62)	(3.56)	(3.08)
Ln (Sale)	1.059***	0.659***	1.055***	0.731***
	(8.30)	(8.63)	(7.50)	(8.19)
Ln (K/L)	-0.631***	-0.213	-0.699***	-0.331**
	(-2.63)	(-1.50)	(-2.65)	(-2.00)
Ln(Firm age)	0.394**	0.268**	0.592***	0.342***
	(2.21)	(2.50)	(2.98)	(2.73)
ROA	0.360	-0.286	0.836	0.0218
	(0.65)	(-0.88)	(1.36)	(0.06)
Ln (Sale growth)	-0.0610	-0.0297	-0.0666	-0.0324
	(-1.35)	(-1.12)	(-1.31)	(-1.03)
Leverage	4.186***	1.784*	5.130***	2.627**
	(2.61)	(1.88)	(2.92)	(2.38)
Tobin's Q	-0.0900*	-0.0292	-0.106**	-0.0444
	(-1.89)	(-1.04)	(-1.98)	(-1.34)
Ind. Effect	Y	Y	Y	Y
Year Effect	Y	Y	Y	Y
N	22,559	22,559	22,559	22,559
Adj. R^2	0.346	0.630	0.475	0.386
Cragg-Donald Wald statistic	29.8	29.8	29.8	29.8
10% critical values of Stock-Yogo weak ID test=19.93				

Table 9

DID robustness tests for the endogeneity of real asset liquidity

Panel A reports DiD tests examining how supply shock in real asset liquidity due to Cold War crash affect firm innovation inputs and outputs. Panel A, Panel B and Panel C reports average change in AL index, Ln (1+ R&D expenditure), Ln (1+patent counts), Ln (1+ ACWCP1), and Ln (1+ ACWCP2) from 1991 to 1992. Treated firms are the firm's size is below 50th percentile in a given year 1990, and control firms are a subsample of the untreated firms selected as the closest match based on sale, probability, Tobin'Q, and leverage in a given year 1990. The panel B reports the regression estimates of change in innovation of treated firms and untreated firms after the end of cold war. The dependent variable is innovation input and innovation outputs. The t-statistics are reported in parentheses below the coefficient with clustered standard error for year. ***, **, and * reported below are significant at the 1%, 5%, and 10% levels, respectively. The definitions of all variables are listed in Appendix.

Panel A: Difference-in-Difference Test

	Treated Firm	Untreated Firms	Treated- Untreated Firms
	(1)	(2)	(3)
ΔLn (1+ R&D expenditure)	0.042	0.037*	0.005
	(1.17)	(1.93)	(0.24)
ΔLn (1+ Patent counts)	-0.050	0.050	-0.100**
	(-0.76)	(1.02)	(-1.98)
ΔLn (1+ ACWCP1)	-0.093	0.052	-0.145
	(-0.71)	(0.13)	(-1.41)
ΔLn (1+ ACWCP2)	-0.084	0.040	-0.125*
	(-1.14)	(0.26)	(-1.87)

Panel B: Difference-in-Difference for Change in Innovation (1991 is the end of Cold War)				
	(1)	(2)	(3)	(4)
	Ln (1+R&D expenditure)	Ln(1+Patent counts)	Ln(1+ACWCP1)	Ln(1+ACWCP2)
TREAT*POSTWAR	0.0140	-0.130***	-0.222***	-0.144***
	(0.25)	(-4.15)	(-13.65)	(-3.27)
POSTWAR	-0.0119	0.188***	0.307***	0.193***
	(-0.34)	(3.32)	(6.56)	(2.97)
TREAT	-0.265	-0.329*	-0.336	-0.348
	(-1.42)	(-1.67)	(-1.31)	(-1.64)
Ln (Sale)	0.797***	0.425***	0.496***	0.424***
	(10.42)	(4.62)	(3.47)	(3.57)
Ln (K/L)	0.138	0.192***	0.448***	0.290***
	(0.97)	(3.14)	(5.84)	(16.62)
Ln(Firm age)	-0.249***	0.169***	0.0452	0.0804***
	(-4.68)	(4.50)	(1.26)	(8.57)
ROA	-2.766***	-0.672	-0.0564	-0.0792
	(-4.50)	(-1.00)	(-0.04)	(-0.07)
Ln (Sale growth)	0.0803***	0.0739***	0.0736*	0.0731***
	(2.61)	(3.29)	(1.77)	(2.78)
Leverage	-1.732***	-0.622***	-0.901***	-0.709***
	(-3.80)	(-3.68)	(-9.63)	(-5.46)
Tobin's Q	0.117***	0.0335	0.0689	0.0207
	(2.92)	(0.53)	(0.93)	(0.30)
Ind. Effect	Y	Y	Y	Y
Year Effect	Y	Y	Y	Y
N	544	544	544	544
Adj. R^2	0.931	0.908	0.953	0.893

Table 10

Firm-level measures of asset liquidity and innovations

The table reports summary statistics on three firm-level measures of total asset liquidity and the regression results. In Panel A the asset liquidity measures include *WAL1*, *WAL2*, *WAL3*, Panel B presents the Pearson correlations of asset liquidity variables (WAL1-WAL3) and innovation variables Ln (1+R&D expenditure), Ln (1+Patent), Ln (1+ACWCP1), and Ln (1+ACWCP2). In Panel C the explanatory variables are WAL1, WAL2, WAL3, as suggested by Gopalan et al. (2012) and Berger et al. (1996). The dependent variable is Ln (1+R&D expenditure), Ln (1+Patent), Ln (1+ACWCP1), and Ln (1+ACWCP2). In the panel regression results, we include industry and year fixed effects. The standard errors are two-way clustered standard errors in firm and year, as suggested by Petersen (2009). The control variables in the models are Ln (Sale), Ln (K/L), Ln (Firm age), ROA, Ln (Sales growth), Leverage, and Tobin's Q. The t-statistics are reported in parentheses below the coefficient. ***, **, and * are significant at the 1%, 5%, and 10% levels, respectively. The definitions of all variables are listed in Appendix

Panel A: Summary statistics

Firm-level measure	Mean	Std. Dev	25%	50%	75%
WAL1	0.158	0.215	0.022	0.069	0.198
WAL2	0.366	0.261	0.177	0.326	0.476
WAL3	0.625	0.233	0.504	0.608	0.719

Panel B: Spearman correlation coefficients

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) WAL1	1.00						
(2) WAL2	0.87***	1.00					
(3) WAL3	0.78***	0.93***	1.00				
(4) Ln(1+R&D expenditure)	0.13***	0.06***	0.001	1.00			
(5) Ln(1+patent counts)	-0.04***	-0.09***	-0.11***	0.61***	1.00		
(6) Ln(1+ACWCP1)	-0.04***	-0.04***	-0.03***	0.44***	0.77***	1.00	
(7) Ln(1+ACWCP2)	-0.04***	-0.06***	-0.06***	0.49***	0.82***	0.94***	1.00

Panel C. Firm-level measures of asset liquidity and innovations				
	(1)	(4)	(5)	(6)
Dependent variable	Ln (1+R&D expenditure)$_{t+1}$	Ln(1+Patent counts) $_{t+1}$	Ln(1+ACWCP1) $_{t+1}$	Ln(1+ACWCP2) $_{t+1}$
WAL1	2.1879***	1.1631***	1.6312***	1.3021***
	(36.97)	(22.99)	(19.81)	(21.55)
Other Control variables	Y	Y	Y	Y
Industry FE & Year FE	Y	Y	Y	Y
N	20,330	20,330	20,330	20,330
Adj. R^2	0.85	0.82	0.87	0.76
WAL2	1.8175***	0.8415***	1.1995***	0.9452***
	(33.50)	(18.28)	(16.17)	(17.20)
Other Control variables	Y	Y	Y	Y
Industry FE & Year FE	Y	Y	Y	Y
N	20,330	20,330	20,330	20,330
Adj. R^2	0.85	0.82	0.87	0.76
WAL3	1.4083***	0.6206***	0.8852***	0.6968***
	(25.02)	(13.34)	(11.75)	(12.51)
Other Control variables	Y	Y	Y	Y
Industry FE & Year FE	Y	Y	Y	Y
N	20,330	20,330	20,330	20,330
Adj. R^2	0.85	0.87	0.87	0.80

Table 11

Real asset liquidity and innovation input by controlling for the effect of stock liquidity

This table is the regression outcome by panel regression with two-way clustered standard errors for firm and year, as suggested by Petersen (2009), and with industry and year fixed effects. The dependent variable is Ln (1+R&D expenditure), Ln (1+Patent counts), Ln (1+ACWCP1), and Ln (1+ACWCP2). The main explanatory variables are WAL1, WAL2, WAL3 as suggested by Berger et al. (1996). We first regress asset liquidity of WAL1, WAL2, WAL3 on stock illiquidity measured by Amihud (2002), respectively, and obtain the regression residuals (Res. AL index, Res. WAL1, Res. WAL2, Res. WAL3). In the second stage, we run the regression of corporate innovations on asset liquidity residuals. The control variables in the model are Ln (Sale), Ln (K/L), Ln (Firm age), ROA, Ln (Sales growth), Leverage, and Tobin's Q, and we only report the main variables. The t-statistics are reported in parentheses below the coefficient. ***, **, and * are significant at the 1%, 5%, and 10% levels, respectively. The definitions of all variables are listed in Appendix A.

Panel A: Firm-Level of Residual Real AL variables				
	(1)	(4)	(5)	(6)
Dependent variable	Ln (1+R&D expenditure)$_{t+1}$	Ln(1+Patent counts)$_{t+1}$	Ln(1+ACWCP1)$_{t+1}$	Ln(1+ACWCP2)$_{t+1}$
Res. AL index	1.7208***	0.9793***	1.2744***	1.0151***
	(17.12)	(11.81)	(9.27)	(10.08)
Other Control variables	Y	Y	Y	Y
Industry FE & Year FE	Y	Y	Y	Y
N	10,234	10,234	10,234	10,234
Adj. R^2	0.87	0.82	0.86	0.75
Res. WAL1	2.3331***	1.2579***	1.7678***	1.3754***
	(34.71)	(20.54)	(17.29)	(18.38)
Other Control variables	Y	Y	Y	Y
Industry FE & Year FE	Y	Y	Y	Y
N	10,289	10,289	10,289	10,289
Adj. R^2	0.87	0.83	0.86	0.75
Res. WAL2	1.8259***	0.8855***	1.2845***	0.9770***
	(29.24)	(15.50)	(13.76)	(14.04)
Other Control variables	Y	Y	Y	Y
Industry FE & Year FE	Y	Y	Y	Y
N	9,839	9,839	9,839	9,839
Adj. R^2	0.87	0.83	0.86	0.75
Res. WAL3	1.3513***	0.6533***	0.9313***	0.7170***
	(20.63)	(11.36)	(9.86)	(10.20)
Other Control variables	Y	Y	Y	Y
Industry FE & Year FE	Y	Y	Y	Y
N	9,839	9,839	9,839	9,839
Adj. R^2	0.87	0.82	0.86	0.75