Corporate Liquidity, Financial Constraints and Capital Investment

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Abstract

This study builds upon research in the financial constraints literature by examining its one-sided effect on the frictionless level of capital investment. While earlier studies rely upon the estimation of investment cash flow sensitivities to infer the presence of financial constraints, we apply the Stochastic Frontier Model developed by Wang (2003) to a sample of US manufacturing firms from 1971-2016 to obtain firm-specific estimates of investment efficiency (financial constraints). We first demonstrate the validity of these constraints measures across the time dimension by providing evidence of a decline in investment efficiency (i.e. an increase in the severity of financial constraints) during periods of economic crises and tightening of monetary policy. We then present further evidence at the cross section, by showing that firms with lower estimates of investment efficiency are more likely to exhibit characteristics which are associated with information asymmetry problems. In light of the documented decline in investment-cash flow sensitivities (Chen & Chen, 2012), we further examine the impact of cash flow on capital investment and the degree of financial constraints. Our results suggest that while the effect of cash flows in mitigating financial constraints has indeed dampened over time, their role in alleviating financial constraints continue to remain relevant.

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1 Introduction

This study examines the severity of financial constraints by exploiting its one-sided effect on the level of capital investment. While it is widely accepted that the presence of capital market frictions lead to firms being restricted from obtaining external finance and will consequently deter investment from being undertaken at an optimal level, the extent of such financial constraints continue to be debated. There has been recent evidence documented however, that popular measures of financial constraints often perform poorly and misidentify constrained firms. This is largely due to financial constraints being unobservable, with prior studies having to rely on proxies for the degree of informational problems to infer the magnitude of constraints faced by firms.

One commonly adopted approach to infer the presence of financial constraints has been thourgh the reliance on investment-cash flow sensitivities (ICFS). Despite the widespread use however, there remain several problems associated with such a research methodology. One common critique of the use of ICFS has been the reliance on split-sample regressions, which require firms to be classified into different sub-samples based upon a proxy for the degree of information asymmetry problems faced by the firm, before the ICFS for each group of firms are estimated. As discussed in Hu and Schiantarelli (1998), it is unlikely that the use of a single metric is able to successfully proxy for the information asymmetry problems underlying each sub-sample and reliably differentiate between constrained and unconstrained firms.

At the same time, the research design employed to estimate ICFS restricts firms to remain in either a constrained or unconstrained regime throughout the entire period of the study. This precludes the possibility of firms potentially experiencing differing financial status at different points in time and requires the assumption that constrained firms will strictly belong in the constrained sub-sample and vice-versa. Such an assumption is unrealistic however and improbable to hold over extended time periods where macroeconomic perturbations are likely to affect the ease of access to external finance.

In light of the deficiencies associated with the use of ICFS to infer financial constraints, this paper attempts to re-examine the impact of cash flow on capital investment and the extent to which a firm can be considered to be financially constrained. We apply the model of Stochastic Frontier Analysis (SFA) on financial constraints derived by Wang (2003) to a sample of US firms from 1971-2016. The use of SFA presents several advantages over the reliance on ICFS to infer financial constraints. First, it circumvents the problems associated with the use of an ad-hoc classification criteria. In addition, firm-specific estimates of constraints can be obtained by observing the deviation of actual investment from the efficient frontier. Not only will this allow for the analysis of the investment decisions for each individual firm in the presence of financial constraints, the model allows for the analysis of the impact of macroeconomic shocks on firms access to finance.

We present highly plausible estimates of investment efficiency and perform cross-sectional analysis on the relationship between financial constraints and various accounting variables that have been used as a proxy to differentiate between constrained firms. We document evidence of this relationship being non-monotonic, highlighting the ambiguous nature of these ad-hoc proxies. Our results demonstrate the limitations of relying on such measures to proxy for financial constraints. We also present inter-temporal evidence on the validity of our estimates by examining the evolution of financial constraints over time. Given that the availability of external finance is associated with the monetary stance and the state of the economy, one can expect an increase in the severity of financial constraints to coincide with periods of macro-economic shocks and contractionary monetary policy. We document consistent results of a significant decline in the average investment efficiency following episodes of monetary tightening and during years of economic recessions.

In addition, we provide a potential explanation for the recent documented disappearance of ICFS (Brown & Petersen, 2009; Chen & Chen, 2012) by presenting evidence of an increase in the average investment efficiency since 1971. We argue that the diminishing economic and statistical significance of ICFS could possibly be attributed to the decline in the severity of financial constraints. We further reconcile this by examining the effect of cash flow on financial constraints. Consistent with prior studies, our results suggest that while the effect of cash flows in mitigating financial constraints has indeed dampened over time, their role in alleviating financial constraints continue to remain relevant.

Finally, we present evidence which point towards the existence of a fight-to-quality during times of economic crises with a differential impact on investment efficiency at the cross-section of firms. While we document a significant drop in the average investment efficiency for the quartile of the smallest firms in the sample around periods of crisis, this remains relatively unchanged for the largest firms. These results suggest that smaller firms experience a detrimental impact on their access to finance following economic shocks. On there other hand, an increase in the severity of financial constraints is not evident for larger firms, which are less likely to be associated with information asymmetry problems and are consequently in a better position to weather economic shocks.

The rest of the paper is organized as follows. The next section provides a review of the prior literature on investment and financial constraints. The research design and the SFA model is presented in section 3 while section 4 describes the data used for the analysis. We discuss our results in section 5. Section 6 concludes.

2 Capital investment and financial constraints

Since the development of the capital structure irrelevance theorem, there have been numerous studies that have sought to examine the financing decisions of firms. Despite research in this area having been well-established however, the question of how firms choose to fund their investment decisions in the presence of financial constraints continue to be debated and remains as one of the main research agendas in corporate finance.

While it was demonstrated in the seminal paper by Modigliani and Miller (1958) that the source of financing is inconsequential in perfect capital markets, with a firm's debt and equity mix having a trivial effect on its value, the presence of market frictions lead to the violation of the conditions required for the MM proposition to hold. This led to the subsequent development of the Pecking Order Hypothesis (Myers & Majluf, 1984), which posits that the costs of financing through various sources will differ as a result of information asymmetry problems. Consequently, this gives rise to the pecking order whereby firms will favour obtaining finance first through internal equity, followed by debt before turning to equity issuance as a last resort.

Several subsequent studies however, have since demonstrated that the 'conventional' pecking order will only be observed under certain restrictive conditions; the violation of which will result in its reversal, where equity will be deemed as more affordable source of funding relative to debt (Nachman & Noe, 1994; Fulghieri, Garcia, & Hackbarth, 2015). While the exact financing behaviour of firms remains unclear and it is uncertain which source of external finance is likely to dominate empirically, it is indisputable that internal funds will prevail as the least costly alternative of finance for their investments.

Given that internal equity is viewed as a more affordable source of financing, it will be a preferred alternative to external finance which will only be utilized once internal funds have been exhausted. At the same time, firms plagued with information asymmetry problems that are sufficiently severe will be entirely priced out of external finance and solely reliant on internal funds. Therefore, an equity shock in the form of positive cash flows would allow for investment projects, which would have previously been deemed infeasible, to now be undertaken. Building upon this argument, it is evident that positive cash flows could serve to alleviate financial constraints with a strand of literature dedicated towards examining the sensitivity of firm investment to internal cash flow.

This is illustrated in Figure 1, where a firm's demand for funds is depicted by the Marginal Product of Capital (MPK) curve which is in turn determined by a firm's investment opportunity set. In the absence of capital market imperfections, internal equity can be substituted with external funds interchangeably. Consequently, firms face a horizontal Marginal Cost curve of funds given by MC^* where any shortfall in financing can be supplemented using external finance, either through borrowing or equity issues, at no incremental cost. Under such circumstances, the optimal level of investment occurs at I^*, where the MPK curve meets the MC^* curve.

In reality however, the presence of capital market frictions often lead to a cost premium for external funds with the user cost of capital increasing in the level of external finance required, rendering it either undesirable or unaffordable. As a result, it is evident that the source of financing will be pertinent as internal/external funds can no longer be perceived as perfect substitutes. Certain investment projects might be deemed unprofitable in the face of costly financing as firms are now faced with an upward sloping supply curve (MC) of external funds, beyond C. Consequently, certain investments which would have otherwise been undertaken in a'first-best' setting would have to be forgone as a result of firms being denied access to affordable funding with actual level of investment undertaken occurring at I as depicted in Figure 1.

Given the widely accepted notion that internal equity can be considered the most affordable source of funds, numerous studies have attempted to test the existence of financial constraints by examining the investment behaviour of firms following a positive shock to internal funds. Originating from the pioneering work of Fazzari, Hubbard, and Petersen (1988), this strand of literature relies on estimates of ICFS by measuring the responsiveness of a firm's investment level to cash flow to infer the existence/extent of financial constraints faced by firms, with a larger ICFS taken to be reflective of a greater severity of financial constraints.

As demonstrated by Tobin (1969), one can expect corporate investment to be solely determined by a firm's investment opportunities and absent any market frictions, Marginal Q should serve as a sufficient statistic in explaining the level of investment undertaken by a firm. This insight implies that firms will continue to invest as long as the market value of an additional unit of capital exceeds its replacement cost (Q greater than 1). In the absence of any significant financial constraints, a firm's investment opportunities should be sufficient in explaining the level of investment undertaken, as a value maximizing firm will not be restricted from external finance and continue to invest as long as Q exceeds unity.

Building upon this result from Q-theory, studies on ICFS largely rely on an a priori classification criterion to partition the sample into groups which are adjudged to face differing severity of financial constraints. The following regression model is then estimated for each sub-sample to test the hypothesis of financing constraints:

$$\frac{Investment_{it}}{K_{it-1}} = \alpha_i + \beta_1 \frac{CF_{it}}{K_{it-1}} + \beta_2 Q_{it} + \epsilon_{it} \tag{1}$$

where Q_{it} serves to proxy for a firm's investment opportunities while $\frac{CF}{K}$ represents a firm's cash flow, scaled by the firm's capital stock at the beginning of the period. The investment response to cash flow (ICFS) is then captured by cash flow coefficient, β_1. For the sub-sample of firms which are deemed to be unconstrained, the predictions of Q-theory would suggest that a firm's investment opportunities are sufficient in explaining firm investment behaviour and cash flows should play a trivial role in a firm's investment decision.

For the sub-sample of firms which are financially constrained however, the lack of available (affordable) funds could potentially restrict firms from the 'first-best' level. Therefore, firms which are financially constrained and were initially priced out of costly external finance are likely to respond to a positive shock to cash flow by increasing their investment levels following accordingly.

As a result, Tobin's Q will no longer be the sole determinant of capital investment as other liquidity variables could load significantly in regressions of investment on Q.

While prior studies have relied upon various proxies to partition firms, the original study by Fazzari et al. (1988) classify firms into sub-samples on the basis of their dividend payout ratios. The rationale for doing so was that firms which pay majority of their earnings as dividends are expected to be able to do so because of their ability to access capital markets with ease, should there be a need to raise funds externally. Conversely, firms which retain a large portion of their earnings are likely to face an increased cost of external funds and as a result, avoid having to do so by saving out of positive cash flows or building financial slack. Therefore, firms with a higher percentage of dividend payout are deemed less likely to be financially constrained.

In doing so, the authors documented significantly positive ICFS across each sub-sample with the magnitude of investment-cash flow sensitivities increasing monotonically in the degree of constraints (i.e. firms that pay out the highest proportion of dividends also exhibit the greatest investment sensitivity to cash flow). This led the authors to conclude that investment-cash flow sensitivities as being representative of financial constraints which restrict the ability of firm's to undertake investment efficiently.

This result is illustrated graphically in Figure 2 where Panel A depicts the supply curve of a more constrained firm (MC_c), as seen by the steeper slope, while the relatively unconstrained firm faces a supply curve with a gentler slope (MC_u) reflecting the smaller premium required in obtaining funding. Similar to Figure 1, investment levels (I_c and I_u) are lower than the amount of investment that would have been taken in perfect capital markets. Following a positive shock to cash flow however, a firm's cash reserve increases from C to C', shifting the supply curve to MC_c' and MC_u' for the constrained and unconstrained firm respectively. In light of this endowment in cash, a new equilibrium level is attained where the marginal cost of capital is equal to the marginal product and investment levels will readjust upwards accordingly to I_c' and I_u'.

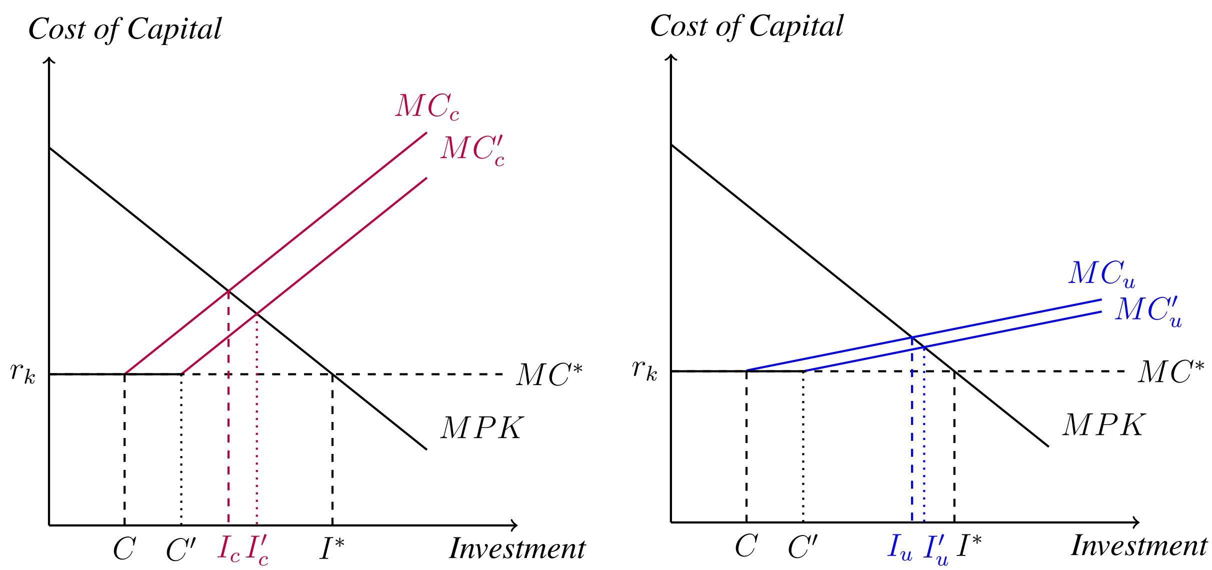

Figure 1: Sensitivity of investment to positive cash flow shocks

The are a number of reasons why we can expect firms to adjust their level of capital stock following a positive shock to cash flow. First, the presence of adverse selection leads to credit rationing, where firms are restricted from obtaining external financing and are therefore financially constrained (Stiglitz & Weiss, 1981). An increase in cash flow will permit firms to utilize such funds to pursue further investment which was initially restricted due to the lack of finance.

Second, even if firms were able to obtain external finance, they might forgo certain investments as the premium of external funds would render these investments less desirable. However, internal equity serves as a cheaper source of finance due to the wedge in the cost of internal and external funds. As a result, investment projects which were initially deemed unprofitable will now have a positive NPV following an endowment of cash flow, inducing firms to increase their investment levels accordingly.

As depicted in Figure 2, investment levels are shown to increase for both constrained and unconstrained firms. However, the degree of this increase in investment levels are shown to be quite different. For the constrained firm, the increase in investment of $I'_c - I_c$ is seen to be greater than that of the unconstrained firm ($I_u' - I_u$). This is essentially the key result of Fazzari et al. (1988) where the investment response following a positive cash flow shock is observed to be larger for firms which are deemed to be more constrained.

In the numerous studies that followed on from Fazzari et al. (1988), a consistent theme emerged in showing that firms deemed to be most likely to be plagued by information problems to exhibit the greatest ICFS. These studies adopt alternative classification criteria to differentiate between firms which were likely to be facing differing extents of capital market frictions and consequently, varying severity of financial constraints. Some of the criteria adopted by these studies include sorting firms on the basis of business group affiliation (Hoshi, Kashyap, & Scharfstein, 1991) or the availability of rated debt (Gilchrist & Himmelberg, 1995). Despite the slightly different classification schemes adopted however, similar results were documented nonetheless, showing that firms which were adjudged ex-ante, to be financially constrained, to also exhibit a greater sensitivity of investment to cash-flow.

Despite the significant number of studies having documented consistent results in support of ICFS being reflective of financial constraints however, there remain several limitations on the use of such methods to infer the presence of constraints (Kaplan & Zingales, 1997; Hu & Schiantarelli, 1998). One common critique stems from the fact that Tobin's Q might be inaccurately measured and fails to sufficiently proxy for a firm's underlying investment opportunities. Consequently, the significance of cash flow in the estimation of equation (1) could be attributed to its correlation with factors unrelated to a firm's liquidity such as its relationship with future profitability instead.

When estimating ICFS, we essentially attempt to measure a firm's investment response to cash flow, as given by $\frac{\partial I}{\partial CF}$. It is important to note however, that positive cash flow shocks are not strictly exogenous and could be the result of an improvement in capital productivity. As a result, an increase in cash flow might not lead solely to an alleviation of constraints but coincide with an improvement in the marginal product of capital as well. This would lead to a rightward shift of not just the MC curve but also the MPK curve. An increase in the level of investment can therefore be attributed to a rise in both the demand and supply of capital. Since the effect on the marginal product of capital is unpredictable and not homogeneous across firms, the increase in investment following a cash flow shock will not be consistent, bringing the reliability of ICFS as a representation of financial constraints into question.

Another common criticism of relying on ICFS to infer financial constraints can be attributed to the use of an ad-hoc classification criteria to sort firms into subsamples with differing costs of external finance. These measures often rely on a single indicator which are highly endogenous in nature with its underlying relationship with financial constraints unclear. The validity of ICFS as a measure of financial constraints is contingent upon the ability of the classification criteria to partition firms facing differential costs of external finance as depicted by the two graphs in Figure 1. As shown in a recent study by Farre-Mensa and Ljungqvist (2016) however, even more 'sophisticated' indexes of financial constraints which have been developed often perform poorly with firms identified to be constrained displaying relative ease in obtaining external finance. Therefore, it is evident that the absence of a reliable criteria to accurately partition firms into sub-samples with varying severity of financial constraints greatly undermines the use of ICFS as a financial constraints measure.

Finally, there have been several studies that have documented a relatively recent decline in ICFS with some suggestions of ICFS having disappeared entirely (Brown & Petersen, 2009; Chen & Chen, 2012). While Chen and Chen (2012) present several explanations for the cause of the documented decline in ICFS, they show that these factors cannot fully account for the disappearance its ICFS and conclude that unless one expects financial constraints to no longer exist, investment-cash flow sensitivities cannot be taken to represent financial constraints.

3 Research design

3.1 Stochastic Frontier Analysis

In light of the aforementioned limitations of the use of ICFS, this study adopts an alternative approach in quantifying financial constraints through an examination of a firm's investment efficiency. This is achieved using methods of stochastic frontier analysis that have been developed to estimate the production (in)efficiencies of firms in its relevant literature, by augmenting the traditional OLS model with an additional one-sided error term. By comparing actual levels of output with its 'theoretical maximum', estimates of production efficiencies can be then obtained.

In a similar spirit, financial constraints can be perceived as inefficiencies that result in the actual level of investment undertaken to bounded from above by the efficient frontier, which can be interpreted as the level of investment that would have been taken by an 'efficient' firm that is not faced with costly external finance. These inefficiencies are therefore representative of the severity of financial constraints experienced by each individual firm. To the extent that the effect of financial constraints are asymmetric and lead to investment taking place below the frictionless level, the firm's investment decision can be similarly modelled through the inclusion of a half-normal (or truncated-normal) error term.

To depict this graphically, we refer to Figure 1 where financial constraints have a one-sided effect of dragging investment leftwards towards the origin, away from the efficient level, I^*. The deviation of actual investment from the 'first-best' level of investment can hence be represented by the shortfall in investment, $I^* - I$. Therefore, the inclusion of a one-sided error term using SFA attempts to capture the extent to which actual investment deviates from the optimal level $I^* - I$; which is driven the severity of financial constraints faced.

The use of stochastic frontier methods can hence be seen as an improvement on the use of ICFS by avoiding the need for an ad-hoc classification criteria altogether. In addition, SFA enables us to obtain observation-specific estimates of inefficiencies (constraints). Not only does this allow for the analysis of financial constraints at the cross-section but also for the examination of the inter-temporal effects of financial constraints. The latter advantage is particularly beneficial, allowing for an investigation into the causes behind the alleged decline in ICFS over time which has been labelled a puzzle by Chen and Chen (2012).

Despite the merits of stochastic frontier analysis however, it has yet to be widely adopted in the financial constraints literature and has only been implemented in the context of developing countries. While it might appear as a natural setting to apply SFA methods in less developed economies to examine the effects of financial liberalization on the alleviation of financial constraints and its effectiveness in stimulating corporate investment, the aforementioned advantages make it intuitively appealing to extend such analysis to developed markets as well. We extend the model in Wang (2003) to a sample of US firms from 1971-2016 to examine the effects of financial constraints on capital investment. In doing so, we document the evolution of financial constraints over time and attempt to reconcile our results with those obtained from the estimation of ICFS.

As discussed in the preceding section, there are several drawbacks to the use of ICFS to infer the presence of financial constraints which render such an approach unreliable and the effects of financial constraints on capital investment can be better measured through the use of SFA techniques. Rather than relying on tests of excess sensitivity of investment to liquidity variables, the one-sided effect of financial constraints on the frictionless (optimal) level of investment can be more accurately modelled through an asymmetric error term giving us the SFA model in the generalized form:

$$Y_{it} = \alpha + \mathbf{X}'_{it}\beta + e_{it} \tag{2a}$$

$$e_{it} = v_{it} - u_{it} \tag{2b}$$

$$v_{it} \sim \mathcal{N}(0, \sigma_v^2) \tag{2c}$$

$$u_{it} \sim \mathcal{N}^{+}(\mu_{it}, \sigma_u^2) \tag{2d}$$

Unlike equation (1), the vector of explanatory variables, $\mathbf{X}_{it}$ in equation (2a) solely consists of factors related to a firm's underlying investment opportunities which serve to determine the level of investment in frictionless markets with liquidity factors excluded from the specification. The error term e_{it} can be further decomposed into the random error term, v_{it}; and the technical inefficiency term which measures the one-sided effect of financing constraints, u_{it}. As seen from (2d), u_{it} follows a truncated normal distribution with mean, μ_{it} and variance, σ_{it}^2. The non-negative truncation of u_{it} ensures that the effects of financial constraints translate into the actual level of investment undertaken always occurring below the efficient frontier.

As seen from the foregoing equation, the model specification only accounts for the estimation of the efficient frontier and has yet to consider the effect of variables that could affect the extent of financial constraints. The SFA model incorporates the role of these factors through modelling of the heteroskedastic variance of u_{it} as shown by Wang and Schmidt (2002), such that:

$$\mu_{it} = a + \mathbf{Z}'_{it}\delta \tag{3a}$$

$$\sigma_{u_{it}}^2 = exp(b + \mathbf{Z}'_{it}\omega) \tag{3b}$$

where a and b are constants while $\mathbf{Z}'_i$ represents a vector consisting of variables which affect the extent of financial constraints faced by a firm. While earlier studies impose the assumption of a half-normal error term ($\mu_{it} = 0$) (Caudill, Ford, & Gropper, 1995; Aigner, Lovell, & Schmidt, 1977), we allow for added flexibility in the model by permitting u_{it} to follow a truncated normal distribution. This more generic specification requires the estimation of both μ_{it} and $\sigma^2_{u_{it}}$ as shown above. We consider both specifications of the model with the estimation results presented in later sections.

3.2 Model specification

This section presents the model specification which builds upon the solution to the firm's optimization problem by Wang (2003) to obtain:

$$\frac{I_t}{K_{t-1}} = \alpha + f(\mathbf{X}_{it}) - g(\mathbf{Z}_{it}) + \epsilon_t \tag{4}$$

Equation (4) shows that the level of investment undertaken, relative to existing capital stock, is a function of the firm's underlying investment opportunities, $f(\mathbf{X}_{it})$. $\mathbf{Z}_{it}$ relate to the variables which determine the extent of financial constraints which restricts the level of actual investment to occur below the frictionless level. In the case of perfect capital markets, $g(\mathbf{Z}_{it}) = 0$ and investment will take place on the efficient frontier. Combining equations (2), (3) & (4), we present the model that we estimate, adjusted to accommodate the True Fixed Effects specification in Greene (2005):

$$ln(Inv_{it}) = \alpha + \beta_1\, ln(Q_{it}) + \beta_2\, ln(Sales_{it}) + \epsilon_{it} \tag{5a}$$

$$\epsilon_{it} = f_i + v_{it} - u_{it} \tag{5b}$$

$$v_{it} \sim \mathcal{N}(0, \sigma^2_v) \tag{5c}$$

$$u_{it} \sim \mathcal{N}^+(\mu_{it}, \sigma^2_u) \tag{5d}$$

$$\mu_{it} = a + \mathbf{Z}'_{it}\delta \tag{5e}$$

$$\sigma^2_{u_{it}} = exp(b + \mathbf{Z}'_{it}\omega) \tag{5f}$$

Consistent with Wang (2003), we include CF/K and $ln(Size)$ as variables in $\mathbf{Z}_{it}$. $ln(Size)$ is used to proxy for the extent of informational problems which could give rise to financial constraints, with smaller firms being typically more susceptible to these effects[1]. CF/K is used to proxy for net worth effects which aid in alleviating the severity of financial constraints (Hubbard, 1998). The inclusion of CF/K also allows for further investigation into the alleged decline in ICFS as we seek to examine if the role of cash flows in determining investment has indeed changed over time. To account for firm-level heterogeneity that is unrelated to financial constraints, the firm fixed effect, f_i is included to distinguish it from u_{it} (Greene, 2005).

4 Data

Data is obtained from the Compustat fundamentals annual database from 1970-2016. The variables used to proxy for the firm's investment opportunity set are $Tobin's\ q$ and $Sales/K$. $Tobin's\ q$ is measured by the market to book ratio of the firm's assets while $Sales/K$ is calculated as total sales for the period scaled by opening net property, plant and equipment. The **Z** variables which aid in explaining the constraint variable, u_{it} are measured by the natural logarithm of assets, $ln(Asset)$ and cash flow for the period scaled by opening period capital stock CF/K.

Consistent with majority of the studies on the literature, only manufacturing firms with 2-digit SIC codes beginning with 20-39 are kept in the sample. Further data filters require firms to have total book value of assets, total sales and the market value of equity to exceed \$1 million while observations with sales or asset growth greater than 100% are dropped from the analysis. To demonstrate the changes in firm characteristics over time, the descriptives statistics are broken down by decade and reported in Table 1. The top 4 panels report the descriptive statistics for the

[1] Firm size is a commonly used proxy in the literature for the informational problems faced by firms (Gilchrist & Himmelberg, 1995). Not only do larger firms have more extensive resources to provide as collateral to overcome problems which arise out of information asymmetry, these firms are more likely to have established financial reporting channels that attempt to improve accounting transparency.

Table 1: Descriptive Statistics

	Obs.	Median	Mean	Std.Dev.	Min	Max
1971-1980						
Investment	13,516	0.2150	0.2796	0.3251	0.0017	15.6977
Tobinsq	13,516	0.9559	1.1781	0.7730	0.3174	9.9749
Sales	13,516	5.6342	7.2535	8.0751	0.2470	287.6364
CF	13,516	0.3616	.4487	.48712	-4.9734	6.7782
Size	13,516	73.524	555.348	2,137.343	1.416	56,576.6
1981-1990						
Investment	15,755	0.2109	0.2866	0.3267	0.0006	9.7083
Tobinsq	15,755	1.1745	1.4013	0.7892	0.3235	9.9669
Sales	15,755	4.9617	6.7144	10.3103	0.0562866	922.4893
CF	15,755	0.3248	0.3885	0.6820	-5.9047	7.4142
Size	15,755	108.297	1,159.55	5,338.316	1.054	180,236.5
1991-2000						
Investment	17,324	0.2009	0.2846	0.3779	0.0007	23.0554
Tobinsq	17,324	1.3595	1.7310	1.1679	0.3062029	9.994274
Sales	17,324	4.8079	7.5253	10.0183	0.0479	238.8658
CF	17,324	0.3335	0.4166	1.0218	-6.7042	7.5695
Size	17,324	169.2425	2,376.495	11,217.34	1.112	303,100
2001-2016						
Investment	23,464	0.1714	0.2367	0.2783	0.0006	10.94
Tobinsq	23,464	1.4196	1.7271	1.0712	0.1727	9.9873
Sales	23,464	5.4204	8.5251	13.3682	0.0234612	698.7809
CF	23,464	0.3689	0.4240	1.2656	-6.8505	7.8128
Size	23,464	494.77	6,969.795	27,393.25	1.336	479,921
Total						
Investment	70,059	0.1958	0.2680	0.3258	0.0006	23.0554
Tobinsq	70,059	1.2394	1.5489	1.0135	0.1727	9.9943
Sales	70,059	5.1979	7.6254	11.0290	0.0235	922.4893
CF	70,059	0.3474	0.4190	0.9723	-6.8505	7.8128
Size	70,059	171.281	3,289.862	17,231.35	1.054	479,921

Table 1 presents the descriptive statistics for the data from 1971-2016. The top 4 panels report the descriptive statistics for the periods 1971-1990, 1981-1990, 1991-2000 and 2000-2016 respectively. The descriptive statistics for the entire sample is summarized in the bottom panel. *Investment* is measured by total capital expenditure in period t scaled by total capital assets at the beginning of the period (t-1). *Tobinsq* is measured by the market to book value of assets. *CF* is measured by total cash flow from operations in period t, scaled by total capital assets at t-1. *Size* is measured by the book value of total assets. The data presented in this table have been winsorised at the 1st and 99th percentile.

period of 1971-1980, 1981-1990, 1991-2000 and 2001-2016 respectively, while the entire sample is summarized in the bottom panel.

5 Results & analysis

We estimate the SFA model as specified in equation (5)[2] and present the results in Table 2. In the interest of comparison with the estimated ICFS presented in Table 3, columns (2) to (5) report the SFA results from 1971-1980, 1981-1990, 1991-2000 and 2001-2016 respectively. Results from 1971-2016 for the entire pooled sample are presented in column (1).

Results from the frontier estimation of equation (5a) show the effect of a 1% increase in Tobin's q on investment has fluctuated between 0.13% to 0.22% over the sample period, while investment is seen to increase between 0.67 to 1 percent for a percentage increase in sales. Due to the non-linearity of the model, we ignore the coefficient of the $\mathbf{Z}$ variables and only draw attention to its sign. The negative coefficients of the $\mathbf{Z}$ variables (ω) suggest an inverse relationship with the inefficiency term. This indicates that an increase in cash flow or firm size results in a decrease in u_{it}, reflecting lower inefficiency as a firm would be undertaking investment at a level closer to the frictionless/efficient frontier. This is consistent with our expectations of larger cash flows and book value of assets leading to a decline in the severity of financial constraints.

To establish a benchmark for the basis of comparison, we estimate equation 1 to obtain the ICFS parameters over the sample period and report them in Table 3. Columns (1) - (4) present the results for the periods of 1971-1980, 1981-1990, 1991-2000 and 2001-2016 respectively. We break down the analysis for each decade to demonstrate the alleged decline in ICFS over time. While the estimates of ICFS we obtain differ numerically from Chen and Chen (2012), we attribute this to the

[2] Estimation of the SFA model is performed on Stata 14 using the user-written *sfpanel* command by Belotti, Daidone, Atella, and Ilardi (2015).

Table 2: Stochastic Frontier Estimation of Corporate investment from 1971-2016

	(1) 1971-2016	(2) 1971-1980	(3) 1981-1990	(4) 1991-2000	(5) 2001-2016
Frontier					
Tobinsq	0.2293	0.2168	0.2131	0.1325	0.2225
	(0.0070)	(0.0162)	(0.0184)	(0.0141)	(0.0120)
Sales	0.6721	1.0583	1.0077	.97867	0.6932
	(0.0056)	(0.0173)	(0.0146)	(0.0128)	(0.0094)
usigma					
CF	-0.2178	-0.1809	-0.2336	-0.5764	-0.0928
	(0.0108)	(0.0421)	(0.0279)	(0.0147)	(0.0118)
Size	-0.4050	-0.7471	-0.5762	-0.5999	-0.5692
	(0.0132)	(0.0269)	(0.0186)	(0.0186)	(0.0162)
Constant	1.0198	1.8581	1.7645	1.9399	2.1833
	(0.0341)	(0.0856)	(0.0629)	(0.0627)	(0.0577)
N	70,053	13,447	15,613	17,205	23,406
Log-likelihood	-65,210	-9,080	-11,490	-12,310	-18,290

Table 2 displays the estimation results of equation (5) with a half-normal distribution of the inefficiency term u_{it}. Column (1) reports the results for entire sample from 1971-2016. Columns (2) - (5) report the results for the periods of 1971-1980, 1981-1990, 1991-2000 and 2001-2016 respectively. The dependent variable for all models are ln(CPX/K), which is measured by the natural logarithm of the ratio of capital expenditure to capital stock. Log(Tobinsq) and Log(Sales) are measured by the natural logarithm of Tobin's q and the natural logarithm of the sales to capital ratio respectively. All models include CF and Size as **Z** variables, where CF is measured by the ratio of cash flow to capital stock while and size is the natural logarithm of the book value of total assets. Standard errors are in parentheses.

difference in sample used as a result of pooling the pooling of firms in our analysis [3]. As evident from Table 3, our results are qualitatively similar to those by prior studies with the coefficient on CF declining monotonically over time, from 0.248 for 1971-1980 to 0.036 since the year 2000. This reaffirms that ICFS has indeed declined over time and points towards a diminishing role for cash flow in explaining capital investment levels. A similar interpretation of ICFS as Fazzari et al. (1988) would suggest that on average, firms have become less financially constrained over time.

[3] The analysis by Chen and Chen (2012) is separated into firms belonging to either the durables, non-durables or high-tech industry. Their estimation of equation (1) is then performed over periods of 5 years each. The smaller number of observations for each regression would result in larger standard errors and is likely to explain the statistically insignificant coefficients reported.

Table 3: Fixed effects estimation of Investment-Cash Flow Sensitivities

	(1) 1971-1980	(2) 1981-1990	(3) 1991-2000	(4) 2001-2016
CF	0.2341	0.1180	0.0799	0.0381
	(0.0072)	(0.0047)	(0.0037)	(0.0017)
Tobin's q	0.0243	0.0656	0.0169	0.0280
	(0.0052)	(0.0050)	(0.0038)	(0.0024)
Constant	0.1099	0.2142	0.2014	0.2091
	(0.0117)	(0.0100)	(0.0107)	(0.0074)
N	13,787	16,255	17,624	23,707
Adj. R^2	0.1471	0.0945	0.0686	0.0571

Table 3 displays the output from the estimation of equation (1). Columns (1)-(4) present the results for the periods of 1971-1980, 1981-1990, 1991-2000 and 2001-2016 respectively. The dependent variable is measured by the ratio of capital expenditure scaled by beginnning of period capital stock. *CF* is measure by cash flow for the period scaled by beginning of period capital stock while the variable *tobinsq* is measured by the market to book ratio of assets. Each column has accounted for firm fixed effects and year fixed effects. Standard errors are in parentheses.

5.1 Validation – Inter-temporal evidence

To obtain the observation specific measures of financial constraints, we derive the point estimates of the inefficiency term ($\hat{u}_{it}$) using the solution proposed by Jondrow, Lovell, Materov, and Schmidt (1982). We then translate these estimates into a measure of investment efficiency given by $exp(-\hat{u}_{it})$ (Battese & Coelli, 1988)[4]. Therefore, one can expect the least financially constrained firms to exhibit the greatest levels of investment efficiency and vice-versa.

To examine the changes in financial constraints over the period from 1971-2016, the average investment efficiency is calculated for each year and plotted in the top panel of Figure 2. The bottom panel plots the percentage change in the total level of debt securities and loans in the US economy from 1971-2016. Data is obtained from the website of the US Federal Reserve. The grey areas represent periods of economic recessions identified by the NBER while the dashed lines indicate years identified as Romer and Romer dates[5] (Romer & Romer, 1989, 1994).

[4] The measure of investment efficiency measures the relative distance between the level of actual investment and the efficient frontier. The measure is bounded from 0 to 1 and a firm with an investment efficiency of 1 would imply

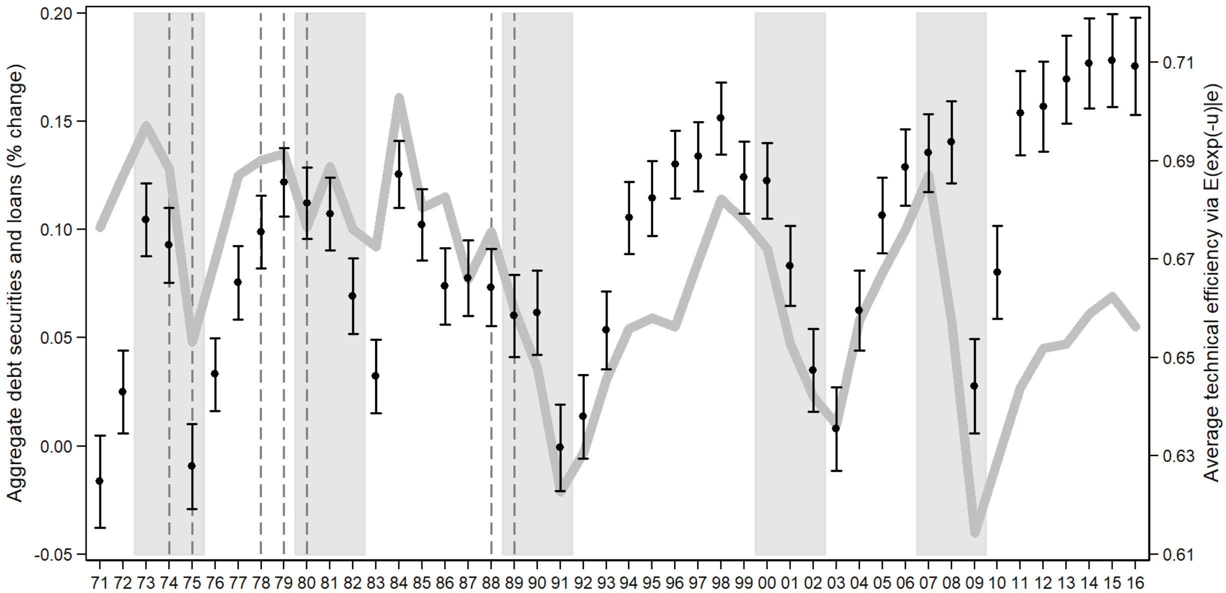

Figure 2: Average Investment Efficiency and % Change in Debt Securities and Loans Issued

As seen from Figure 2, the level of investment efficiency has fluctuated around 62 to 72% over the period. While not strikingly obvious, it can be seen that the average efficiency has shown a slight increase in each decade over time. Removing the effects of the Global Financial Crisis of 2008, an upward trend can be observed since 2002. While the increase in investment efficiency (decrease in financial constraints) coincides with the documented disappearance of ICFS, it can be seen that financial constraints for the average firm in each year are still very much significant with the average investment efficiency hovering around the 72% mark since 2010.

More compellingly however, Figure 2 identifies several distinct periods of a significant decline in the average investment efficiency – the few years following 1975, the early 1980s and 1990s, 2001-2003 and the Global Financial Crisis in 2008/2009. These years coincide with periods where one would expect firms to face a greater severity of financial constraints – the economic recessions identified by the NBER or the Romer and Romer dates of tight monetary policy. External

that it is 100% efficient and hence, entirely unconstrained.

[5] The Romer and Romer dates are identified by Romer and Romer (1989, 1994) and represent episodes of tight money brought about by contractionary policy.

finance would likely to have been costly during these periods, resulting in a credit squeeze which would have accentuated the severity of financial constraints and the observed decline in average investment efficiency. The decrease in credit circulating the economy can be seen in the bottom panel, where there is an evident decline in the percentage change of the aggregate levels of debt securities and loans in the US. As evident from Figure 2, the years in which declines in the average investment efficiencies are documented conform with periods in which financial constraints were likely to have been more severe.

To examine the periods of increased financial constraints in greater detail, we first look at the decline in investment efficiency in 1974/75. While the NBER recognised the start of the recession in late 1973, the decline in investment efficiency did not occur till after 1974. With 1974 identified as a Romer and Romer date, the increase in the degree of financial constraints was likely to have been brought about by the contractionary stance of high interest rates by the Federal Reserve to combat inflation. Similarly, another significant decline in investment efficiency began in 1980 with a Romer and Romer date identified in late 1979. This worsening of financial constraints would have been contributed by the federal funds rate being raised by up to 3.75%, in an effort to further reign in inflation.

The next distinct period of increased financial constraints can be traced to 1989, starting with an initial marginal decline in investment efficiency. It is worth noting that December of 1988 was identified as a Romer and Romer date with another round of monetary tightening following relatively low interest rates in the preceding years. The credit crunch of the early 90's as documented by Bernanke and Lown (1991) would have led to a subsequent worsening in the severity of financial constraints and the significant drop in investment efficiency observed in 1991.

As there were no subsequent studies following Romer and Romer (1994) whose sample ended in 1991, the last episode of monetary tightening identified by Romer and Romer dates was December of 1988. It remains evident nonetheless, that ensuing declines in investment efficiency can be largely attributed to the incidence of well-documented crises. The first period of declining investment efficiency post-1991 coincides with the bursting of the 'dot-com' bubble in 2000. With depressed market values following massive declines in stock prices during this period, one would expect financing through equity issues to be costly. Similarly, the collapse of numerous companies would have led to greater caution being exercised by credit providers further restricting access to debt funding.

The dot-com bubble was then followed by a series of accounting scandals involving Enron and WorldCom which led to the passing of the Sarbanes-Oxley act in 2002. The effects of the implementation of SOX has been widely studied and has been shown to have resulted in a significant increase in compliance costs for listed companies. Taken together, these events were once again would have resulted in an increase in the severity of financial constraints, leading to the decline in investment efficiency observed. Finally, the decrease in investment efficiency as seen in 2009 can be attributed to the GFC which took place in 2008. Considered to be the worst financial crisis since The Great Depression, an increase in the severity of financial constraints during this period is hardly surprising with credit availability declining tremendously and the financial health of banks being brought into question.

As evident from Figure 2, the SFA model performs well across the time-dimension with inter-temporal inferences largely consistent with our expectations. Years in which significant drops in the average investment efficiency (financial constraints) were observed coincide with periods where the cost of external finance were likely to have been higher.

As seen from the above discussion, the one-sided error term of SFA is undoubtedly one of the key features of the model. Therefore, we perform further analysis using alternate specifications of u_{it} to test the sensitivity of our results. We first consider the generic specification for the technical inefficiency to follow a truncated normal distribution such that $u_{it} \sim \mathcal{N}^{+}(\mu_{it}, \sigma_u^2)$, where $\mu_{it} \neq 0$. We also allow for the exponential distribution of u_{it}.

In addition to allowing for alternative specifications of the distribution of u_{it}, we address concerns that arise from the pooling of observations. As SFA attempts to measure the investment shortfall relative to the frictionless level, we require the assumption of the frontier function remaining constant throughout. Therefore, the extended time period over which the analysis is performed would make it susceptible to the shifts in the frontier attributable to technical change. To mitigate concerns that our estimates of inefficiency are capturing a shift in the frontier rather than changes in inefficiencies, we repeat the estimation of the SFA model for all three specifications with the inclusion of time fixed-effects. Our results are presented in Table 4.

Table 4: Stochastic Frontier Estimation of Corporate investment from 1971-2016

	Half-normal	Truncated-normal		Exponential	
	(1)	(2)	(3)	(4)	(5)
Frontier					
Tobinsq	0.3152	0.2275	0.3158	0.2358	0.3155
	(0.0071)	(0.0069)	(0.0071)	(0.0069)	(0.0070)
Sales	0.6634	0.6373	0.6673	0.6761	0.6676
	(0.0055)	(0.0059)	(0.0056)	(0.0056)	(0.0055)
usigma					
CF	-0.1488	-0.1408	-0.2238	-0.2617	-0.1811
	(0.0092)	(0.0074)	(0.0151)	(0.0149)	(0.0129)
Size	-0.5773	0.3117	-0.3120	-0.4731	-0.6701
	(0.0090)	(0.0082)	(0.0198)	(0.0128)	(0.0118)
Constant	1.7998	0.4031	1.2353	0.2129	1.1163
	(0.0326)	(0.0240)	(0.1053)	(0.0481)	(0.0447)
N	70,053	70,053	70,053	70,053	70,053
Log-likelihood	-60,170	-62,600	-60,040	-64,780	-60,170
Time Fixed-effects	Y	N	Y	N	Y

Table 4 displays the estimation results of equation (5) with various alternate specifications for the distribution of the inefficiency term u_{it}. Column (1) reports the results for the stochastic frontier model where $u_{it} \sim \mathcal{N}^{+}(0, \sigma^2)$. Columns (2) and (3) adopt the more general truncated normal distribution where $u_{it} \sim \mathcal{N}^{+}(\mu_{it}, \sigma^2)$, with the inclusion of time fixed effects (τ_t) for column (3). Columns (4) and (5) present the alternate specification of the inefficiency term with an exponential distribution, with the inclusion of τ_t for column (5). The dependent variable for all models are ln(CPX/K), which is measured by the natural logarithm of the ratio of capital expenditure to capital stock. Log(Tobinsq) and Log(Sales) are measured by the natural logarithm of Tobin's q and the natural logarithm of the sales to capital ratio respectively. All models include CF and Size as **Z** variables, where CF is measured by the ratio of cash flow to capital stock while and size is the natural logarithm of the book value of total assets. Standard errors are in parentheses.

As seen in Table 4, our results do not change with the alternate specifications. While the coefficients of the **Z** variables have changed in sign for the reported estimates in column (2), it should be noted that even the sign for coefficients are misleading for the truncated normal model as the effect of **Z** on u_{it} is dependent on both the functions for μ_{it} and σ_u^2, as shown in equation 5(e) and 5(f). To ensure that the inefficiency estimates for each model are not significantly different from each other, we compute Spearman-rank correlations of u_{it}. We obtain rank correlation coefficients in excess of 0.9 (significant at the 1% level) for all specifications except for the estimates from the model in column (2). We believe this can be attributed to the flexibility of the truncated normal specification by allowing μ_{it} to vary, rendering it sensitive to the omission of time effects which does not permit for technical change in the frontier function.

In observing the log-likelihood ratios reported in Table 4, it can be seen that the truncated-normal model with time fixed effects is the statistically preferred specification. Therefore, we repeat the analysis of the average investment efficiency over time (as previously reported in Figure 2) using the estimates of u_{it} from model (2) and present them in Figure 3.

Similar to Figure 2, significant drops in investment efficiencies can be observed during periods of increased financial constraint as previously discussed. More strikingly however, the level of investment efficiency is seen to be trending upwards over time. Despite the average firm exhibiting similar levels of investment efficiency at 65% in 1971 as shown in Figure 2, this rises significantly to just below 80% by the end of the sample period. This would suggest that the average firm is less constrained in 2016 than it was in 1971 and that investments are now undertaken more efficiently than they previously were before. These results can be potentially reconciled with those of Chen and Chen (2012), with the disappearance of ICFS possibly explained by a decline in the severity of financial constraints documented.

The results we have presented thus far are encouraging if the frictions deterring investment from occurring at the efficient level are indeed less pervasive than they were in the past. It remains

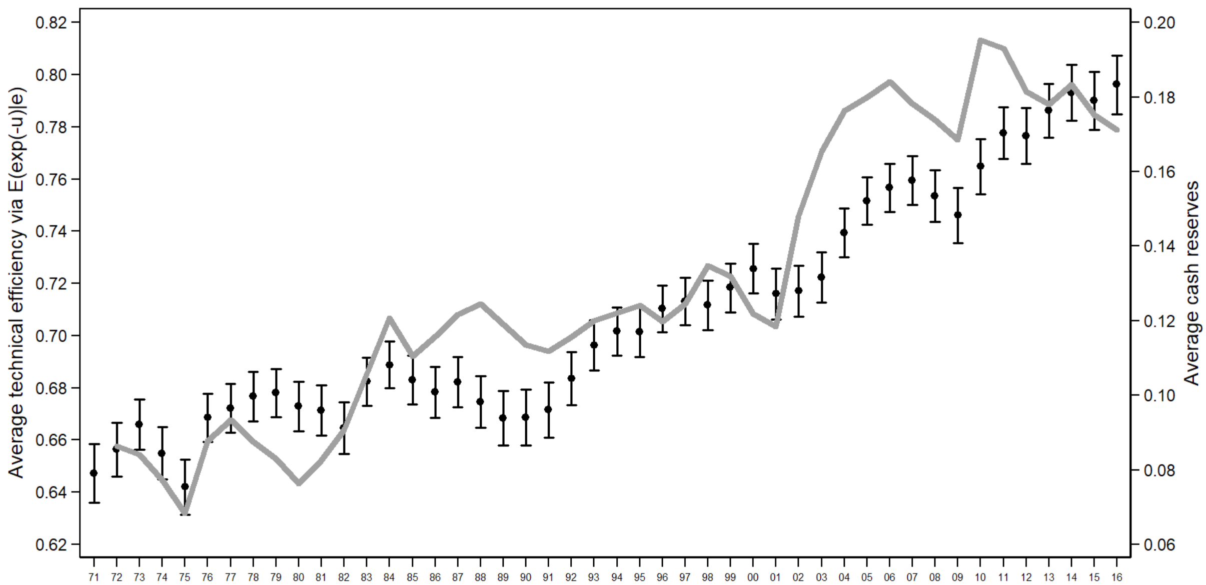

Figure 3: Investment Efficiency and CCE/Total Assets Over Time

a question however, as to what factors can be attributed to be the drivers of the documented results. While there have been numerous economic policies and accounting standard which have been implemented during this time period, in the attempt to improve the efficiency of capital markets, it is difficult to attribute the reduction in financial constraints to any one specific event. Nonetheless, we examine one potential explanation for the observed phenomenon by looking at the cash levels of firms over the sample period. We plot the average ratio of cash and cash equivalents to total assets in Figure 3.

With an increasing number of firms worldwide coming under scrutiny for sitting on stockpiles of cash, numerous reasons have been provided to justify the massive amount of cash reserves held by these companies. One explanation that has been put forth, dating as far back as the work of Keynes, is that these increased levels of cash holdings can be justified by precautionary motives. This argument is substantiated by Bates, Kahle, and Stulz (2009), who show that precautionary motives were a critical determinant of the build-up in cash reserves with no evidence of the increase in cash ratios being driven by tax reasons or agency problems. Incidentally, the build-up occurred most significantly in the 90's, coinciding with the distinct rise in investment efficiency that we document.

It appears highly plausible that the build-up in cash reserves could serve as one possible explanation for the improvement to the average investment efficiency as having additional cash on hand will reduce the reliance on costly external finance, allowing for investments to be undertaken close to the efficient frontier. While the factors contributing to the decline in financial constraints warrants further investigation, we note that this is not the main objective of the paper and leave it for future research. Instead, we present further cross-sectional evidence on the validity of the estimates of financial constraints we obtain through the SFA model.

5.2 Cross-sectional evidence

Having examined the validity of the estimates of financial constraints across the time dimension, we now present cross-sectional results from the SFA model. As previously discussed, one of the main criticisms of the use of ICFS has been the reliance on split-sample regressions. The lack of a sound classification criteria thoroughly undermines such a method with recent work by Farre-Mensa and Ljungqvist (2016) demonstrating that popular measure of constraints that are often used as sorting criteria often misidentify firms.

Following the approach of Wang (2003), we sort observations into quintiles according to one of the following accounting variables – firm size, dividend payout ratio, cash and cash equivalents, short-term debt and long-term debt. The latter three variables are scaled by the book value of total assets. The average investment efficiency is calculated for each quintile and plotted in Figure 4. In addition to evaluating the cross-sectional validity of the efficiency estimates this allows us to examine how financial constraints relate to widely used proxies in the literature. While the relationship between constraints and firm size might be relatively straightforward, this is less apparent for potentially endogenous firm characteristics such as debt and cash reserves. While firms with low levels of debt might be construed as unconstrained and capable of acquiring further leverage, it could well be that such firms are in fact constrained and the low debt levels observed are a result of being priced out of external finance.

As seen in Figure 4, the average investment efficiency rises monotonically only across the quintiles of size and long term debt. These results indicate that larger firms tend to be less financially constrained while the same can be said for firms with higher long-term debt-to-asset ratios. This would suggest that being able to acquire additional debt serves to alleviate the extent of financial constraints faced by firms.

Turning to the graphs of cash and cash equivalents and short-term debt however, a distinctly similar pattern across quintiles for both variables can be observed. While the average investment efficiency increases monotonically for the first four quintiles, a significant decline is evident for the final quintile of firms with the highest cash and short-term debt ratios. We interpret this to be evidence of firms with higher cash reserves and short-term debt to be generally less financially constrained. As observed from the non-monotonic relationship however, there exists a point beyond which a higher cash/ST debt ratio might not necessarily translate into a lesser degree of financial constraints. Instead, it would appear that for firms in the highest quintile of short-term debt ratios, the decline in investment efficiency is likely to be contributed by liquidity constraints induced by impending debt maturity.

We observe similar non-monotonicity of investment efficiency across quintile of dividend payout ratios which would bring the findings of Fazzari et al. (1988) into further question. These graphs highlight the endogenous nature of such proxies of financial constraints and the problems from classifying firms into sub-samples when estimating ICFS. The difficulty in identifying critical values upon which to split the samples further undermines ICFS as a measure of financial constraints and could cloud our inferences.

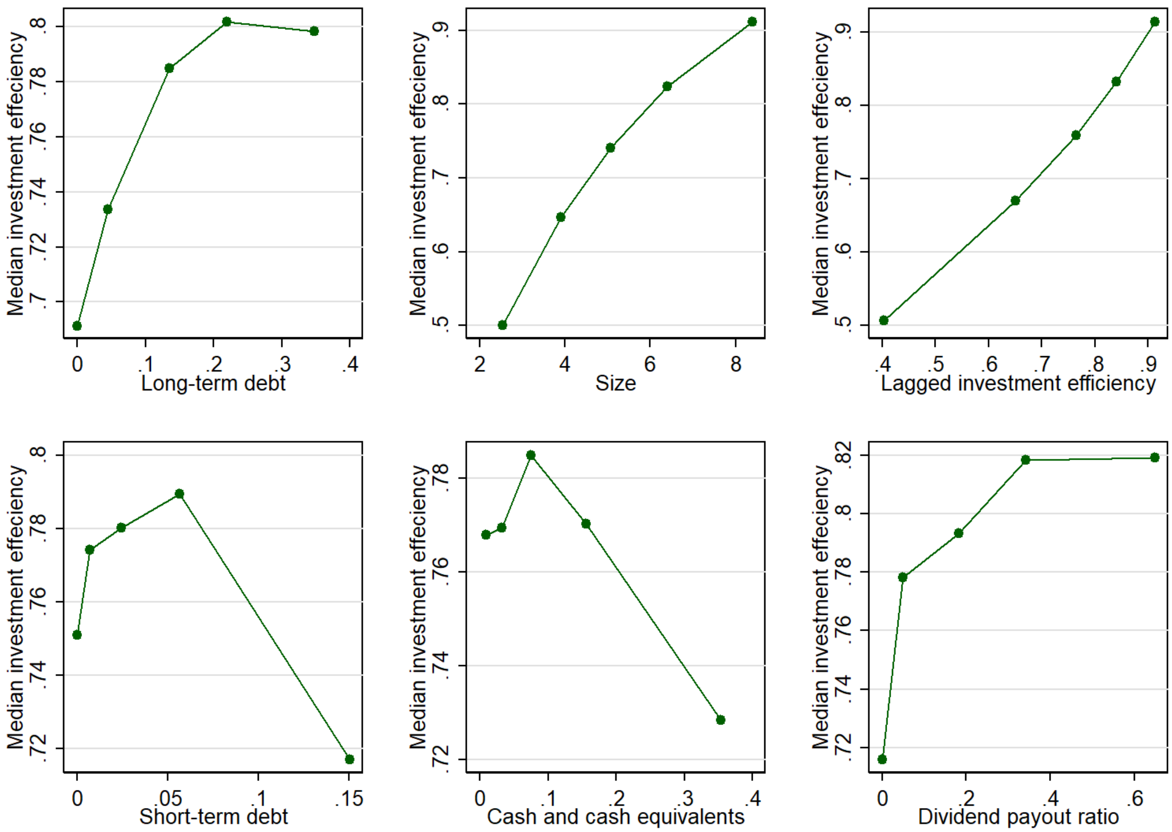

Figure 4: Relationship Between Average Investment Efficiency and Firm Characteristics

Finally, we examine the change in investment efficiency for firms by first sorting observations into quintiles on the basis of the estimated efficiency in the previous year. We then compute the average investment efficiency for each quintile in the current period and plot it in the top right graph of Figure 4. The observed linear relationship across quintiles indicate that constrained firms exhibit the tendency to remain constrained while firms with high efficiency in the previous period tend to continue being highly efficient.

To further investigate the change in financial status across adjacent periods, we compute the transition probabilities and report them in Table 5. The rows of Table 5 represent the deciles of investment efficiency in period $t-1$ while the columns represent the deciles of investment efficiency in period t. Therefore, the cell in the r^{th} row and c^{th} column reports the percentage of

Table 5: Transition Probabilities

	1	2	3	4	5	6	7	8	9	10
1	45.661	22.376	13.055	7.218	4.346	2.966	2.118	1.318	0.753	0.188
2	20.615	25.289	20.174	13.505	8.618	5.572	3.685	1.705	0.731	0.107
3	11.952	19.073	20.849	18.787	12.720	8.641	4.501	2.574	0.783	0.120
4	7.491	12.145	16.889	19.336	18.631	12.746	8.017	3.453	1.171	0.120
5	4.589	7.993	12.208	16.797	19.391	18.011	13.092	5.849	1.905	0.165
6	3.089	5.621	7.520	11.784	16.682	21.308	20.268	10.775	2.697	0.256
7	2.036	3.129	4.986	6.857	11.259	17.128	25.498	21.964	6.678	0.464
8	1.659	2.006	2.534	3.484	5.701	9.532	16.863	35.294	21.750	1.176
9	0.909	0.833	0.924	1.136	1.985	2.848	5.166	16.437	56.749	13.013
10	0.183	0.092	0.061	0.138	0.245	0.214	0.443	1.009	8.941	88.675

Table 5 presents the transition probabilities across deciles of investment efficiency. The rows represent the deciles of investment efficiency in period $t-1$ while the columns represent the deciles of investment efficiency in period t. Therefore, the cell in the r^{th} row and c^{th} column reports the percentage of firms that move from the r^{th} decile in period $t-1$ to the c^{th} column in period t. The columns in each row add up too 100%.

firms that move from the r^{th} decile in period $t-1$ to the c^{th} column in period t. The columns in each row add up too 100%. As observed across the diagonal of Table 5, there is considerable inertia in moving between deciles with majority of firms remain in the same decile of financial constraints as they were in the prior year. While the probability of transitioning to a neighbouring decile diminishes significantly the further away it is from the decile in the previous year, it is evident that a firm's financial status is dynamic. This once again demonstrates the limitations of ICFS in inferring financial constraints, with firms classified as belonging to a particular financial status forced to remain in the same regime through the analysis.

5.3 The role of liquidity in determining investment

Having verified the validity of our estimates across the time dimension and at the cross-section, we now turn our attention to the role of cash flows in determining investment and examine its effect on financial constraints.

As previously mentioned, the reported coefficients of the **Z** variables in Table 4 are potentially

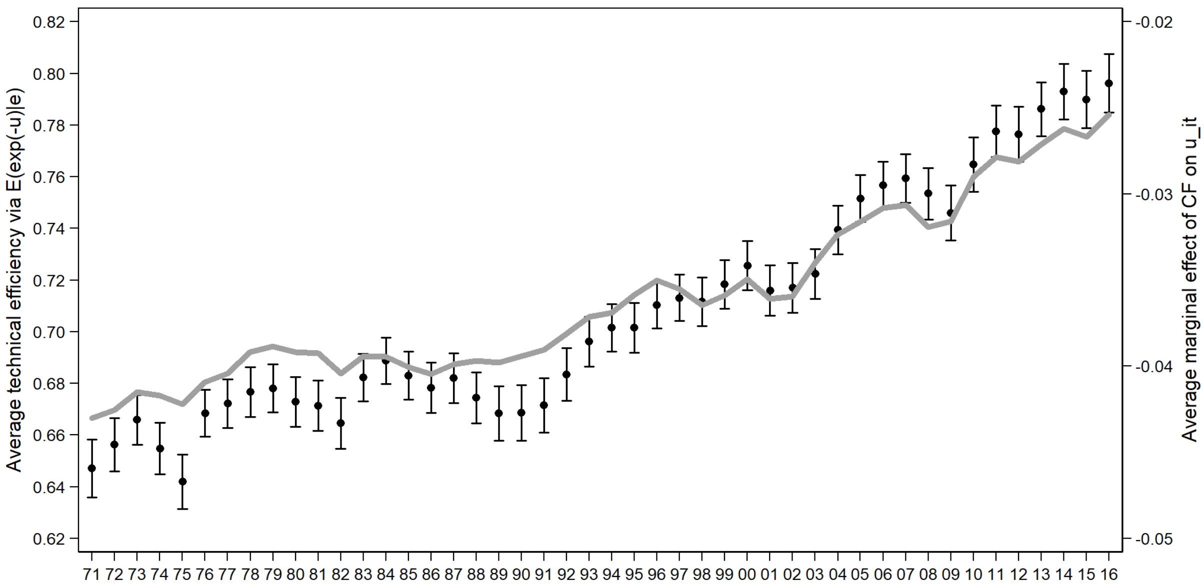

Figure 5: Marginal Effects of CF and Size/Investment Efficiency

misleading, given the non-linearity of the inefficiency functions. Therefore, we rely on the actual realizations of the $\mathbf{Z}$ variables to derive the marginal effect of cash flow on u_{it} for each observation. As before, we compute the average marginal effect across all firms for each year and plot the results in Table 5.

As evident from the graph, there is once again an upward trend observed over time with the average marginal effect of cash flow on financial constraints rising from just below -0.04 to around -0.02 in 2016. The negative sign is consistent with our understanding of the liquidity effects of cash flow and indicates that a positive cash flow shock will lead to a decrease in financial constraints. This suggests that the average effect of cash flow in mitigating financial constraints has nearly halved over the sampled period. Consistent with the decline in ICFS, the upward trend towards zero can be interpreted as a diminishing significance of cash flow in mitigating financial constraints. Taken together, these results suggest that a firm which is less financially constrained will be less reliant on cash flows while an increase in cash reserves will similarly reduce a firm's dependence on cash flows.

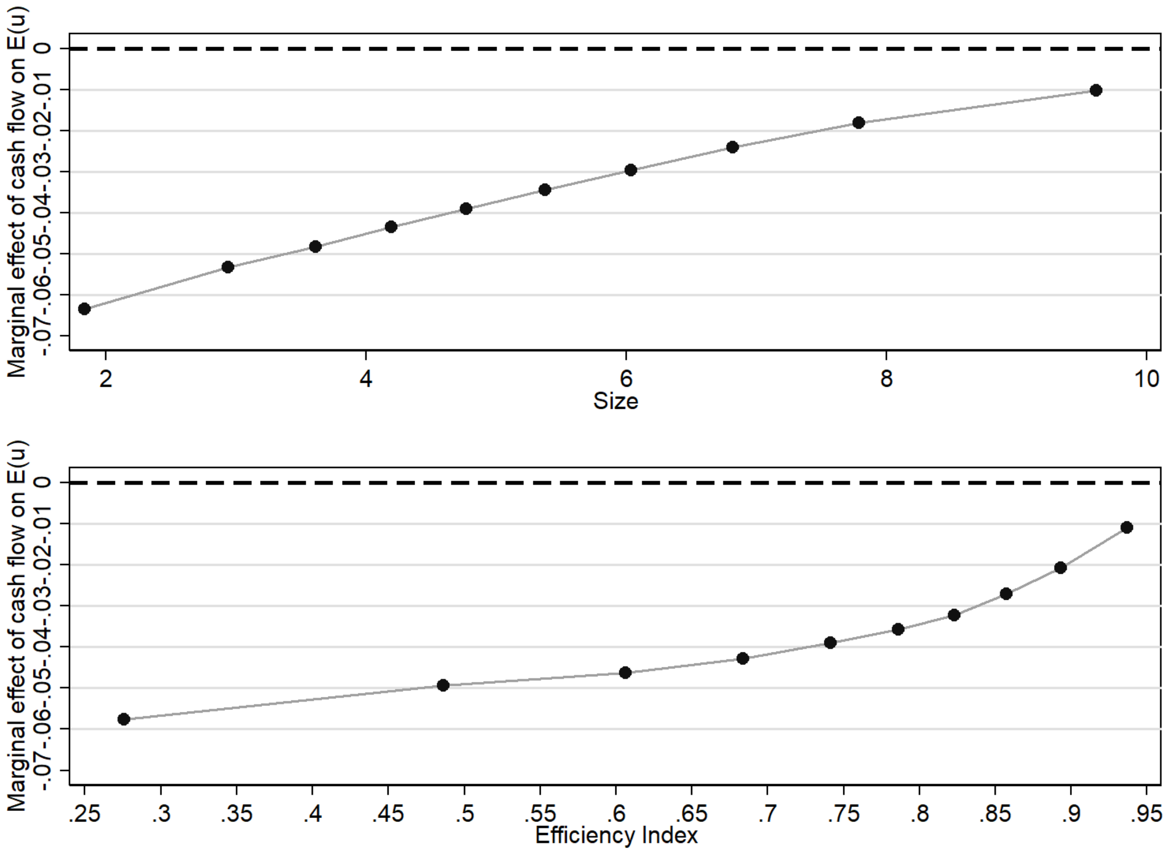

Figure 6: Marginal Effects of CF and Size/Investment Efficiency

To further verify the diminishing significance of cash flows on investment and its marginal effects on financial constraints, we sort observations by the size of their total assets and their estimates of investment efficiency and derive the marginal effects of cash flow on u_{it} for each decile respectively. The results are presented in Figure 6. Consistent with Figure 5, the role of cash flows in alleviating financial constraints is observed to diminish as firms progress towards deciles of higher investment efficiency. This is an intuitive result which demonstrates that the liquidity effects of cash flows are most important for the firms which face the largest severity of financial constraints. Likewise, larger firms are less likely to be priced out external finance and are consequently less reliant on cash flows to mitigate financial constraints.

5.4 Financial constraints and the flight-to-quality

Thus far, we have presented evidence confirming the validity of the estimates of financial constraints obtained through the SFA model. In keeping with our prior expectations, we have shown that the average severity of financial constraints are exacerbated during periods of crisis or monetary tightening. At the same time, results obtained at the cross section indicate that firms with characteristics that are less likely to to be associated with informational problems exhibit higher levels of investment efficiency. In this section, we combine both sets of results to present evidence of a flight to quality during periods of economic crises.

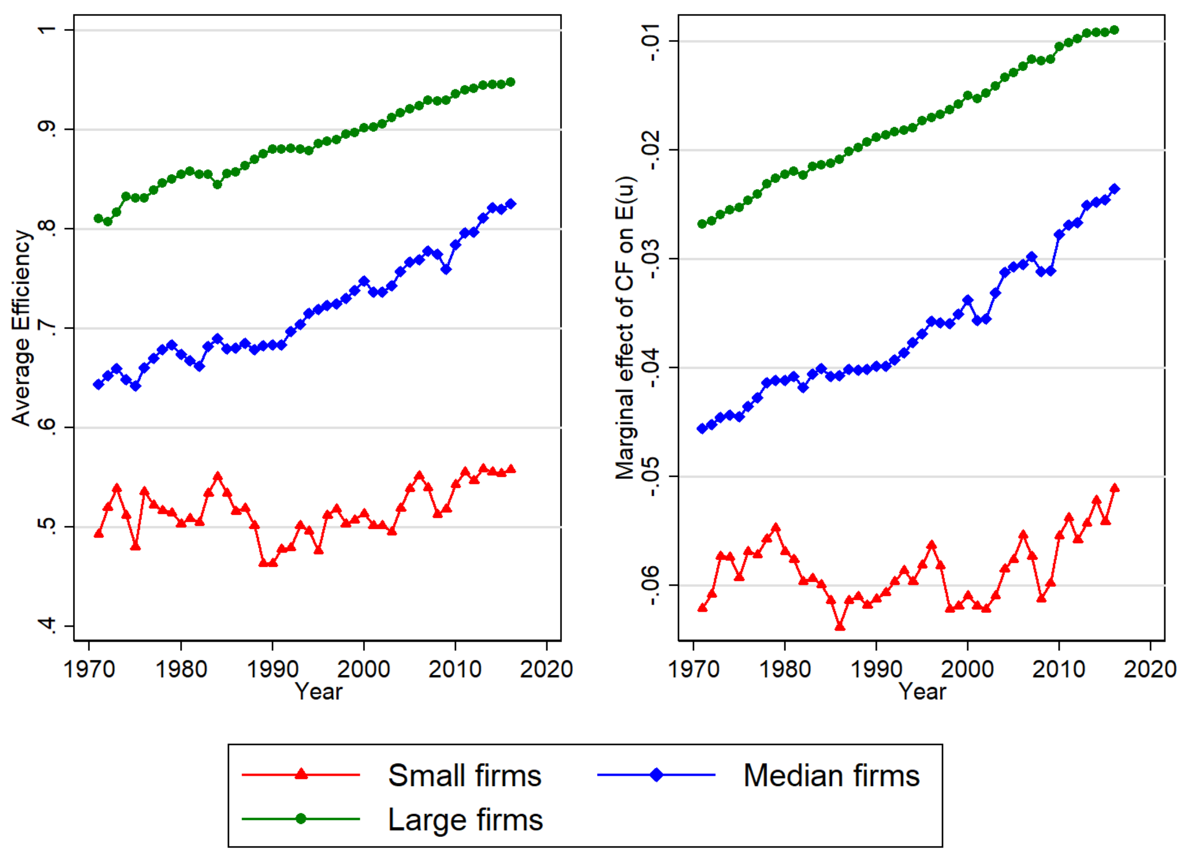

Figure 7: Changes in Average Investment Efficiency/Marginal Effects by Firm Size Over Time

Consistent with the notion that smaller firms are more susceptible to informational problems, we separate observations into quartiles on the basis of firm size. Observations from the first and last quartile are labeled as the largest and smallest firms respectively while the remainder are labeled as medium sized firms. We compute the average investment efficiency for each class of firms at each point in time and plot the results in Figure 7. Consistent with our earlier results, the extent of financial constraints faced by a firm is related to its size with that largest quartile of firms exhibiting the most highest level of average investment efficiency of over 80%. This is followed by medium-sized firms with slightly lower investment efficiencies compared to the largest firms, rising from an efficiency level of around 65% at the start of the sample period to just over 0.8 in 2016.

Despite distinct improvements in efficiency levels for these firms however, this trend does not appear to apply to the smallest quartile of firms with efficiency levels continuing to hover around the 50% mark throughout the sample period. More interestingly however, the smallest firms appear to be most significantly affected by financial constraints during the periods of crises previously identified, with a notable decline in average efficiency levels. This decline is less pronounced for the median firms with the effect barely noticeable for the largest quartile of firms. Our results point towards the existence of informational problems for the smallest firms with the observed decline in investment efficiency likely to be driven by the lack of availability of external finance, subsequently hampering their ability to undertake profitable investments.

This unavailability of external finance does not appear to impact the largest quartile of firms with the decline during years of crises or monetary tightening largely negligible. There are several explanations for this observed phenomena. As well-documented in the accounting literature, larger firms are less likely to be associated with informational problems with more established reporting mechanisms in place. In addition, larger firms tend to belong to more mature industries where the business operations/conditions are better understood by market participants. At the same time, the greater book value of assets at their disposal could serve as collateral to overcome the additional cost of external funds brought about by information asymmetry.

These factors could certainly lead to larger firms being favoured by lenders/investors to help weather the impact of an adverse economic shock while the detrimental effects of informational problems are accentuated for smaller firms. While financial constraints can be seen to remain relevant for medium-sized firms, they appear to be better equipped to handle such shocks with the decline in investment efficiency less pronounced relative to that of the smallest firms.

Turning to the right-hand panel of Figure 7, a similar trend can be observed for the average marginal effect of cash flow on financial constraints. The role of cash flow in mitigating financial constraints is seen to be greater following adverse economic shocks. This suggests a greater dependence on internal equity during such these periods. Once again, the reliance on internal cash flow is most pronounced for the smallest firms which is likely to be driven by increased cost of external finance brought about by informational problems. We interpret these results to represent a flight to quality during times of economic crises, with the decline in average efficiency levels driven by the unwillingness of market participants to provide funds to smaller firms.

6 Conclusion

This paper adopts the SFA model developed by Wang (2003) to examine the effect of financial constraints on capital investment. Despite extensive research having been conducted in this area, prior studies are limited by the lack of a sound measure for financial constraints with popular approaches adopted in the literature often resulting in misidentification of constrained/unconstrained firms (Farre-Mensa & Ljungqvist, 2016). We exploit the one-sided effect of financial constraints which restricts actual investment undertaken to always occur below the frictionless level and apply the SFA model to obtain firm-specific estimates of financial constraints for a sample of US firms from 1971-2016.

We evaluate the performance of these measures of financial constraints across the time dimension and at the cross-section. Our results are consistent with the notion that firms face an increased severity in financial constraints following adverse economic shocks, with a documented decline in investment efficiency during periods of economic crises and monetary tightening. Interestingly, we find that the average investment efficiency has increased since 1971 from 65% to around 80% post GFC. This would suggest that the average firm is less financially constrained today than it was in the past which could serve as one potential explanation for the documented decline in ICFS (Chen & Chen, 2012). Indeed, further analysis on the marginal effect of cash flow on financial constraints show that despite a clear role for cash flow in the alleviation of financial constraints, its effect has weakened over the years.

We also present cross-sectional evidence which provide further support on the validity of our financial constraints estimates. While its relationship with liquidity variables such as cash and short-term debt remains ambiguous, we show that investment efficiency increases monotonically with firm size and long-term leverage. These results further highlight the dangers of relying on a single indicator to partition firms which could potentially explain the mixed results documented in the literature on ICFS.

Finally, we document evidence of a flight to quality during episodes of economic crises. While the average investment efficiency for the quartile of smallest firms decline significantly following adverse economic shocks, this does not appear to be the case with the largest quartile of firms. Instead, the largest firms appear to be better equipped to weather economic shocks with the observed investment efficiency remaining largely stable throughout. The greater value of assets at the disposal of larger firms could serve as collateral to mitigate informational problems that drive up the wedge between costly external finance and internal funds. Therefore, these results are reflective of a flight to quality during economic crises, where capital is channeled towards firms with stronger balance sheets, resulting in severity of financial constraints for smaller firms being exacerbated.

While the use of SFA to model financial constraints by prior studies has been limited to the analysis of financial liberalization in developing countries, we demonstrate that this can be easily applied to developed economies such as the US as well. In addition to circumventing the problems known to plague the ICFS literature, the ability of the SFA model to provide observation-specific estimates of financial constraints is likely to allow for a more thorough analysis of its effects on various corporate policies. We leave this for future research.

References

Aigner, D., Lovell, C. K., & Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics*, *6*(1), 21–37.

Bates, T. W., Kahle, K. M., & Stulz, R. M. (2009). Why do us firms hold so much more cash than they used to? *The Journal of Finance*, *64*(5), 1985–2021.

Battese, G. E., & Coelli, T. J. (1988). Prediction of firm-level technical efficiencies with a generalized frontier production function and panel data. *Journal of Econometrics*, *38*(3), 387–399.

Belotti, F., Daidone, S., Atella, V., & Ilardi, G. (2015). Sfpanel: Stata module for panel data stochastic frontier models estimation. *Statistical Software Components*.

Bernanke, B. S., & Lown, C. S. (1991). The credit crunch. *Brookings Papers on Economic Activity*, *1991*(2), 205–247.

Brown, J. R., & Petersen, B. C. (2009). Why has the investment-cash flow sensitivity declined so sharply? rising r&d and equity market developments. *Journal of Banking & Finance*, *33*(5), 971–984.

Caudill, S. B., Ford, J. M., & Gropper, D. M. (1995). Frontier estimation and firm-specific inefficiency measures in the presence of heteroscedasticity. *Journal of Business & Economic Statistics*, *13*(1), 105–111.

Chen, H. J., & Chen, S. J. (2012). Investment-cash flow sensitivity cannot be a good measure of financial constraints: Evidence from the time series. *Journal of Financial Economics*, *103*(2), 393–410.

Farre-Mensa, J., & Ljungqvist, A. (2016). Do measures of financial constraints measure financial constraints? *Review of Financial Studies*, *29*(2), 271–308.

Fazzari, S. M., Hubbard, R. G., & Petersen, B. C. (1988). Financing constraints and corporate investment. *Brookings Papers on Economic Activity*, *1988*(1), 141–206.

Fulghieri, P., Garcia, D., & Hackbarth, D. (2015). Asymmetric information, security design, and the pecking (dis) order. *Working paper*.

Gilchrist, S., & Himmelberg, C. P. (1995). Evidence on the role of cash flow for investment. *Journal of Monetary Economics*, *36*(3), 541–572.

Greene, W. (2005). Fixed and random effects in stochastic frontier models. *Journal of Productivity Analysis*, *23*(1), 7–32.

Hoshi, T., Kashyap, A., & Scharfstein, D. (1991). Corporate structure, liquidity, and investment: Evidence from japanese industrial groups. *The Quarterly Journal of Economics*, *106*(1), 33–60.

Hu, X., & Schiantarelli, F. (1998). Investment and capital market imperfections: A switching regression approach using us firm panel data. *Review of Economics and Statistics*, *80*(3), 466–479.

Hubbard, R. G. (1998). Capitalmarket imperfections and investment. *Journal of Economic Literature*, *36*(1), 193–225.

Jondrow, J., Lovell, C. K., Materov, I. S., & Schmidt, P. (1982). On the estimation of technical inefficiency in the stochastic frontier production function model. *Journal of Econometrics*, *19*(2-3), 233–238.

Kaplan, S. N., & Zingales, L. (1997). Do investment-cash flow sensitivities provide useful measures of financing constraints? *The Quarterly Journal of Economics*, *112*(1), 169–215.

Modigliani, F., & Miller, M. H. (1958). The cost of capital, corporation finance and the theory of investment. *The American Economic Review*, *48*(3), 261–297.

Myers, S. C., & Majluf, N. S. (1984). Corporate financing and investment decisions when firms have information that investors do not have. *Journal of Financial Economics*, *13*(2), 187–221.

Nachman, D. C., & Noe, T. H. (1994). Optimal design of securities under asymmetric information. *The Review of Financial Studies*, *7*(1), 1–44.

Romer, C. D., & Romer, D. H. (1989). Does monetary policy matter? a new test in the spirit of friedman and schwartz. *NBER Macroeconomics Annual*, *4*, 121–170.

Romer, C. D., & Romer, D. H. (1994). Monetary policy matters. *Journal of Monetary Economics*, *34*(1), 75–88.

Stiglitz, J. E., & Weiss, A. (1981). Credit rationing in markets with imperfect information. *The American Economic Review*, *71*(3), 393–410.

Tobin, J. (1969). A general equilibrium approach to monetary theory. *Journal of Money, Credit and Banking*, *1*(1), 15–29.

Wang, H.-J. (2003). A stochastic frontier analysis of financing constraints on investment: the case of financial liberalization in taiwan. *Journal of Business & Economic Statistics*, *21*(3), 406–419.

Wang, H.-J., & Schmidt, P. (2002). One-step and two-step estimation of the effects of exogenous variables on technical efficiency levels. *Journal of Productivity Analysis*, *18*(2), 129–144.