WP-2019-016

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May 2019

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**Abstract**

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**Keywords: Monetary policy, Investment spending, Dynamic System GMM, Interest rate channel, Credit rate channel**

**JEL Code: E4, E5, E6**

**Acknowledgements:**

We would like to thank Prof. B.N. Goldar and an anonymous referee for their constructive comments.

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The study estimates the dynamic panel version of augmented neoclassical investment model using ARDL specification. There are evidences in support of interest rate and credit channels of monetary transmission, both in the short as well as in the long run. Our evidence of interest rate channel is robust and is not driven by outliers on the basis of size, investment to capital and cash flow to capital ratio. We also correct for the presence of financially distressed and constrained firms. The heterogeneous impact of cash flow to capital stock ratio on investment spending of small and large firms provides further evidence in favour of working of credit channel.

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## 1. Introduction

Monetary policy transmission mechanisms explain the manner in which policy decisions are able to impact the real economy. The two main channels, through which monetary policy can influence firm- level investment spending, are through the interest rate and credit channels. Traditional monetary policy transmission mechanisms, such as the interest rate channel, focus on direct effects of monetary policy actions. It is the most dominant channel of monetary policy transmission. Under the interest rate channel, changes in monetary policy are eventually reflected in the real long-term interest rates which influence aggregate demand by changing business investment and durable consumption decisions. This, in turn, gets reflected in aggregate output and prices.

By contrast, the credit channel of monetary policy transmission is an indirect augmentation mechanism that works in sync with the interest rate channel. Changes in interest rate impact the net cash flow available to a firm. Due to the existence of imperfect capital markets in view of information asymmetry, the availability of net cash flow will have a direct impact on the investment spending of firms. Existence of credit channel implies that monetary policy not only affects current interest rates, but also size of the external finance premium through reduced current and expected future profits, which in turn amplifies the monetary policy effect on firm's investment.

Interest rate channel has an influence on the firm's investment spending through the user cost of capital. Firms will adjust their level of capital stock until the marginal productivity of capital would equal the cost of funds given the presence of a perfect capital market. Credit channel will have an impact on firm-level investment through the net cash flow, which differs when interest rate changes are announced. In the presence of imperfect capital markets due to information asymmetry, the availability of net cash flow will have a direct impact on investment (Chatelain et al., 2003). Further, the credit channel view theorizes that monetary policy changes that impact the short-term interest rate are intensified by the endogenous changes in the external finance premium. The external finance premium is a wedge which reflects the difference in the cost of capital internally available to firms (i.e., retaining earnings) as opposed to the firm's cost of raising capital externally through equity and debt markets. External financing is more expensive than internal financing. Therefore, under asymmetric information, the sensitivity of investment spending to cash flow will be different across various firms' classes. Small[3] firms are likely face higher information asymmetry and thus its investment will be more sensitive to the cash flows than those of the large firms.

In examining the importance of the monetary transmission channels, most of the literature has dwelt on the macro level data. However, as has been argued by Chirinko et al. (1999), studies at the aggregate level are not able to find economically significant relationship between investment spending and firm user cost of capital. The reason could be attributed to biased estimates due to the presence of simultaneity, capital market frictions, and firm heterogeneity that micro data might be able to address better. Moreover, by using micro panel data, it is easy to measure firm-level specific variables like capital stock, user cost of capital, cash flow and sales which are useful in estimating the determinants of firm-level investment spending. Additionally, micro data also contains a larger group of information which lies closer to economic theory. For the case of

[3] In order to segment the firms, five groups were created on the basis of total assets. The lowest quintile was treated as small firms and the top quintile was treated as large firms.

India, it is all the more important to study micro data as it will be useful in offering useful policy prognosis based on the results offered by the study.

In this study, the impact of monetary policy on firm-level investment through the interest rate and credit channel will be explored by using firm-level panel data extracted from CMIE's Prowess. The following research design has been used in probing the relevance of both the monetary policy channels: (i) the interest rate channel has been proxied by the user cost of capital as proposed by Chirinko et al. (1999) and Mojon et al. (2002); (ii) the credit channel has been measured through cash flow to capital stock ratio which roughly indicates the liquidity position of a firm; (iii) following Mairesse et al. (1999) disaggregated firm-level investment spending has been estimated using the dynamic neoclassical model, which is derived from the traditional neoclassical model of investment (Jorgenson, 1963) and which links firm-level investment spending to firm-level sales growth and user cost of capital. This neoclassical model has also been augmented by the cash flow to capital stock ratio as in the empirical literature pioneered by Fazzari et al. (1988). The coefficient for cash flow to capital stock ratio may be interpreted as an indicator of the degree of financial constraints facing a firm, since investment of credit-constrained firms are more sensitive to the availability of internal funds, i.e., cash flow.

The contribution of this study to the existing literature in India is manifold. Most of the research studies in India have examined the importance of the two channels of monetary transmission (interest rate and credit channels) by using only macro level data. This is the first study of India as per our knowledge, which has examined the importance of these two channels using firm-level panel data by estimating the neoclassical investment model which links up firm-level investment spending to user cost of capital, cash flow to capital stock and sales growth. Further, the study also examines the heterogeneous nature of monetary policy effects by firm's size (classified as small and large firms on the basis of their total assets size). The study uses Generalized Method of Moments (GMM) proposed by Arellano & Bond (1991); Arellano & Bover (1995) and recently extended by Blundell & Bond (1998). To test for the robustness of the results, bootstrap-based bias corrected FE estimator was computed. The results were broadly in line with the main results and are available on request.

The broad research objectives of this study can be summed up as follows:

**Objective 1**: To investigate the role of the traditional interest rate channel and broad credit channel in influencing the firm-level investment spending.

**Objective 2**: To explore the heterogeneous nature of monetary policy effects by firm size (large and small firms).

The rest of the study is organized as follows:

Section 2 provides the detailed review of literature; section 3 describes the theoretical framework; section 4 discusses the methodology and data selection used in the analysis; section 5 discusses the empirical results and section 6 concludes along with providing the key policy implications.

## 2. Review of Literature

Mojon et al. (2002) analysed the impact of a change in interest rates on firms' investment spending in Germany, France, Italy and Spain using an error correction framework in the dynamic neoclassical model. They found that in each of the four countries a variation in the user cost of capital has both statistically and economically significant effects on investment. In the short-run, the elasticity of user cost of capital with respect to firm-level investment spending ranged from -0.23 (in Italy) to -0.69 (in Spain). Overall, the effect of the user cost on investment spending implies that the interest rate channel of monetary policy is operative in the four Euro Area economies under consideration. Changes in the level of interest rates have an impact on firms' investment through the user cost of capital. Further, the study also finds that while the average interest paid by small firms is significantly larger than the average interest paid by large firms, there is no evidence that the premium paid by small firms, reacts to changes in the interest rate. Additionally, the study found no evidence of the fact that the investment spending of small firms is more sensitive to the user cost of capital than investment spending of large firms.

Karim (2010) examined the impact of monetary policy on firms' fixed-investment spending using a dynamic panel System GMM estimation proposed by Blundell & Bond (1998) in Malaysia. He estimated the firms' investment model by employing a dynamic neoclassical framework in an Autoregressive Distributed Lag (ARDL) model. The study found evidence to back the importance of interest rates and credit channels in transmitting to firms' investment spending. Further, the results also revealed that the impact of monetary policy channels on the firms' investment spending are heterogeneous, implying that the small firms which face higher financial constraints respond more to monetary tightening as compared to the large firms (less constrained firms). Thus, the important policy implication of the study included that the monetary authority needs to consider the microeconomic aspects of firms' behaviour in formulating their monetary policy.

Nagahata & Sekine (2005) investigated the effects of monetary policy on firm investment post the collapse of the asset price bubble in Japan. The authors estimated the augmented accelerator-type firm investment functions using panel data within a first differenced ARDL and Error Correction Model (ECM). They found that the coefficients of the user cost of capital were similar to those found for other industrial economies such as Italy and France. Further, by quantifying the effect of changes in the user cost on firm-level investment, the study showed that the interest rate channel was effective at least in the first half of the 1990s

Guariglia & Mateut (2006) tested for the presence of a trade credit channel of transmission of monetary policy by using a panel of 609 UK firms over the period 1980–2000. They estimated the error correction inventory investment equations augmented with the coverage ratio and trade credit to assets ratio. They found that both credit and trade credit channels of monetary policy transmission are operative side by side in UK, with the latter having stronger effects than the former.

Though, there are many studies done in India to examine the investment behaviour in Indian industries, but none have examined the linkage between investment spending and monetary transmission channels. The important studies which have examined the investment behaviour in Indian industries include Krishnamurthy & Sastry (1975), Sarma (1988) and Kumar et al. (2001). In most of the studies, flexible accelerator model and financial variables have been used to explain investment behaviour.

A comprehensive study on investment behaviour of Indian industries was undertaken by Krishnamurthy & Sastry (1975) using models based on flexible accelerator and financial variables. They analysed both fixed and inventory investment. They presented OLS and 2SLS results of investment function estimation for 7 important industries—cotton textiles, jute textiles, chemicals, engineering, paper & paperboard, sugar and cement. For obtaining estimates based on pooled time-series and cross-section data, the authors did not deflate data for price changes, whereas, in their analysis based on time-series data, price corrections were made. The variables used to explain the gross fixed investment included change in sales, rent profits net of dividend and taxes, flow of net debt, depreciation reserves at the beginning of the year. The authors observed the impact of accelerator on fixed investment only in cotton textiles, jute textiles and engineering industries. Retained earnings and external finance were found to be significant determinants of investment only in cotton textiles, jute textiles, chemicals and engineering. Thus, their results indicated competition of funds between fixed and inventory investment.

Sarma (1988) applied the neoclassical model of investment to make an assessment of investment linked tax allowance in the case of Indian private corporate sector. He used aggregate time-series data for the period 1960–61 to 1982–83. The production function underlying the investment model which he assumed was CES type. For estimating the investment model, the author first estimated the dividend equation and derived the series on the long-run optimal dividend payout ratio. After this, he estimated the debt-equity equation and derived the long-run gearing ratio series. Using these two series and other relevant information (including various tax elements), the rental cost of capital is worked out. This is then used for the estimation of the investment function. His analysis showed that cost consideration plays a significant role in investment decisions. Investment allowance reduces the cost of capital, thus encouraging investments. The results also indicate a significant lag in the adjustment of capital stock to its desired level.

Kumar et al. (2001) investigated the presence of financial constraints on firms' investment behaviour using firm-level data from Prowess for the period 1993–98. In order to test for the presence of financial constraints, the authors related investment in fixed assets to a sales accelerator, cash flow, stock of long-term debt and stock of liquid assets. The study based on OLS found coefficients of internal sources, accelerator term and long-term debt to be positive and significant for all categories of firms. However, the coefficient of liquid assets was found to be negative and significant.

Using data from RBI for firms' belonging to seven Indian industries—textiles, metals, electricals, chemicals, drugs, automobiles and machinery—Pandit & Siddharthan (1998) explained the inter-firm differences in the growth of capital stock using technology acquisition variables. Though variation was noticed among the different industries with regard to the estimated investment model, certain broad trends emerged. The variables such as in-house R&D, intra-firm transfer of technology through foreign equity participation and import of machinery & equipment emerged as important in explaining the investment behaviour of firms.

## 3. The Theoretical Framework

### 3.1 Neoclassical investment model

The neoclassical investment model was developed by (Jorgenson, 1963) and is based on the neoclassical theory of capital accumulation which says that the demand for capital is derived from firm's production function. Appendix at the end gives the detailed derivation. The distinguishing feature of this model is that it is based on the explicit model of optimization. It relates the firm-level investment spending to sales and user cost of capital. This way the relative significance of interest rate channel in monetary transmission process could be examined by checking the sign of user cost of capital in the neoclassical investment model.

By assuming a constant elasticity of substitution (CES), the neoclassical production function can be written as:

$$F\,(L_{it}, K_{it}) = TFP_i A_t \left[\beta_i\, L_{it}^{\;\frac{\sigma-1}{\sigma}} + \alpha_i\, K_{it}^{\;\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}\upsilon} \tag{1}$$

Where, σ is the elasticity of substitution between capital ($K$) and labour ($L$), υ represents return to scale. At any point of time $t$, $TFP_i$ is Total Factor Productivity of firm $i$. Thus, $TFP_i A_t$ has two components and represents total factor productivity (TFP) of firm $i$ in time $t$. The first order condition for a firm's optimisation problem leads to the equality between the marginal product of capital ($F_k$) and the User Cost of Capital ($UC_{it}$) as follows:

$$F_k(L_{it}, K_{it}) = UC_{it} \tag{2}$$

By substituting, equation (2) into equation (1), the first order condition of firm profit maximization is as follows:

$$\log K_{it} = \theta logY_{it} - \sigma logUC_{it} + logH_{it} \qquad \text{or} \qquad k_{it} = \theta y_{it} - \sigma uc_{it} + h_{it} \tag{3}$$

Where, $k_{it}$ is log of capital stock, $y_{it}$ is log of sales, $uc_{it}$ is log of user cost of capital, $\mathrm{h_{it}} = \log\left[(\mathrm{TFP_i\;\; A_t})^{\frac{\sigma-1}{\upsilon}}(\upsilon\alpha_i)^{\sigma}\right]$ is log of total factor productivity and $\theta = \left(\sigma + \frac{1-\sigma}{\upsilon}\right)$. Equation (3) implies that the stock of capital ($k_{it}$) is determined by three factors, namely, firm output or sales ($y_{it}$), firm user cost of capital ($uc_{it}$) and total factor productivity ($h_{it}$).

In the long-run, it is assumed that the firm changes its capital stock in the direction of a long-run target value of k* as follows:

$$k_{it}^{*} = \theta y_{it} - \sigma uc_{it} + h_{it} \quad (4)$$

Since the value of k* is not observable in empirical estimation, therefore in order to estimate equation (4), a new specification in terms of ARDL is used in the study. Such kind of dynamic neoclassical investment model have been estimated by Chatelain et al. (2003); Mairesse et al. (1999); Mojon et al. (2002) and Nagahata & Sekine (2005).

The dynamic neoclassical investment model in ARDL (3,3)[4] can be written as follows:

$$k_{it} = \alpha_1 k_{i,t-1} + \alpha_2 k_{i,t-2} + \alpha_3 k_{i,t-3} + \theta_0 y_{it} + \theta_1 y_{i,t-1} + \theta_2 y_{i,t-2} + \theta_3 y_{i,t-3} + \sigma_0 uc_{it} + \sigma_1 uc_{i,t-1} + \sigma_2 uc_{i,t-2} + \sigma_3 uc_{i,t-3} + \emptyset_0 h_{it} + \emptyset_1 h_{it-1} + \emptyset_2 h_{it-2} + \emptyset_3 h_{it-3} \quad (5)$$

We know that $\Delta k_{it} = \log(K_{it}) - log(K_{i,t-1})$

$$\Delta k_{it} = log\left[\frac{K_{it}}{K_{i,t-1}}\right] = log\left[1 + \frac{K_{it} - K_{i,t-1}}{K_{i,t-1}}\right] == log\left[1 + \frac{I_{it}}{K_{i,t-1}}\right]$$

Where we have used $K_{it} - K_{i,t-1} = I_t$, using the expansion of log(1+x) to linearise log(1+x) ≈ x , we get

$$\Delta k_{it} = \left[\frac{I_{it}}{K_{i,t-1}}\right] \quad (6)$$

Where $\Delta k_{it}$ is the net growth in capital stock[5] (K), $I_{it}$ is the real investment of firm i in year t and $K_{i,t-1}$ is capital stock in period t-1. Equation (6) is substituted in Equation (5) and its first difference taken along with replacing year-specific productivity growth ($\Delta \log A_t$) by time dummies ($\lambda_t$), firm-specific effect productivity ($\Delta \log TFP_i$) by firm-specific effects ($\eta_i$), and adding a random term $\vartheta_{it}$. $h_{it}$ which is present in Equation (5) is dropped since it is an unobservable. After making all the substitutions, the following equation is obtained:

[4] Chatelain el al. (2003) considers an ARDL (3,3) model

[5] Capital stock estimated using Perpetual Inventory Method. Details available on request

$$\left[\frac{I_{it}}{K_{i,t-1}}\right] = \alpha_1 \left[\frac{I_{i,t-1}}{K_{i,t-2}}\right] + \alpha_2 \left[\frac{I_{i,t-2}}{K_{i,t-3}}\right] + \alpha_3 \left[\frac{I_{i,t-3}}{K_{i,t-4}}\right] + \theta_0 \Delta y_{it} + \theta_1 \Delta y_{i,t-1} + \theta_2 \Delta y_{i,t-2} + \theta_3 \Delta y_{i,t-3} +$$

$$\sigma_0 \Delta uc_{it} + \sigma_1 \Delta uc_{i,t-1} + \sigma_2 \Delta uc_{i,t-2} + \sigma_3 \Delta uc_{i,t-3} + \gamma_i + \eta_i + \vartheta_{it} \quad (7)$$

### 3.2 Augmenting the dynamic neoclassical model

Credit channel is another important channel through which monetary policy is able to influence firm-level investment spending. Since the publication of Bernanke's (1986) seminal work there has been considerable literature about the relative importance of the credit and money channels in the transmission of monetary policy. Credit channel assumes importance as small borrowers may not have access to financial markets. Therefore, bank credit is also taken into account along with money and bonds while examining the monetary policy transmission (Khundrakpam & Jain, 2012).

The credit channel view suggests that changes in the external finance premium intensify the monetary policy variations which in turn have an impact on the short-term interest rates. The external finance premium is a wedge which reflects the difference in the cost of capital internally available to firms (i.e., retained earnings) as opposed to the firms' cost of raising capital externally via equity and debt markets. Internal financing is cheaper than the external financing and the external finance premium will exist so long as external financing is not fully collateralised. The cost differential between internal and external finance arises from agency costs and the gap should depend inversely on the borrower's net worth. An increase in interest rates increases the size of the external finance premium and subsequently, through the credit channel, reduces credit availability in the economy. The external finance premium is present because of frictions—such as imperfect information or costly contract enforcement—in financial markets. These frictions hinder in the efficient allocation of resources which in turn results in dead-weight cost.

The credit channel—or, equivalently, changes in the external finance premium—can occur through two channels: the balance sheet channel and the bank lending channel. Under the balance sheet channel, any changes in the interest rates have an impact on the borrowers' balance sheets and income statements. While the bank lending channel suggests that any change in the monetary policy may affect the supply of loans disbursed by the financial institutions.

The size of the external finance premium that results from these market frictions may be affected by monetary policy actions. For example, monetary policy tightening (an increase in interest rates) depresses asset values and the value of collateral and thus increases the cost of external funds relative to internal funds. However, since the agency problems are likely to be more severe for small firms than large firms, the relationship between internal sources of funds and investment spending should be particularly strong for small firms after monetary contraction.

In contrast, agency costs are usually assumed to be lesser for large firms because of the economies of scale in gathering and handling information about their financial situation. As a consequence, large firms can more easily finance directly from the financial market and hence are less dependent on the banking system for procuring loans. For example, Gertler & Gilchrist (1994) argue that small manufacturing firms in the US economy are more sensitive than large firms in response to the tightening of monetary policy over the business cycle. Small firms account for a highly disproportionate share of declines in sales, inventories and short-term debt following monetary tightening. They argued that the small firms were likely to face larger barriers to outside finance than large firms because asymmetric information creates agency problems between the small firms and banks.

Most of the empirical studies have linked the broad credit channel with the firm financial constraints, which is proxied by cash flow. Gertler (1988) and Bernanke & Gertler (1989) have emphasised the role of agency costs, that make external financing sources more expensive for firms than internal sources. Small firms in particular may have difficulty obtaining funding from non-bank sources, so a contraction in bank lending will force these firm to contract their activities, for example investment. In contrast, large firms were likely to be less dependent on bank credit because they will have access to external finance generated from the capital markets. Since cash flow roughly corresponds to changes in available internal funds, higher investment-cash flow sensitivities could be considered evidence of greater financial constraints (Hubbard, 1998).

Thus, based on the above discussion, in order to examine the importance of credit channel in impacting the firm-level investment spending, the proxy of cash flow to capital stock ratio (CFit/Ki,t-1) is used. This ratio gives us an idea that how much cash flow is generated per unit of capital stock. Cash flow is defined as Profit after Tax (PAT) plus depreciation. Cash flow is deflated using WPI based price deflator. Therefore, the augmented version of the neoclassical investment model shown in equation (7) is expressed as:

$$\left[\frac{I_{it}}{K_{i,t-1}}\right] = \alpha_1\left[\frac{I_{i,t-1}}{K_{i,t-2}}\right] + \alpha_2\left[\frac{I_{i,t-2}}{K_{i,t-3}}\right] + \alpha_3\left[\frac{I_{i,t-3}}{K_{i,t-4}}\right] + \theta_0\Delta y_{it} + \theta_1\Delta y_{i,t-1} + \theta_2\Delta y_{i,t-2} + \theta_3\Delta y_{i,t-3} + \sigma_0\Delta uc_{it} + \sigma_1\Delta uc_{i,t-1} + \sigma_2\Delta uc_{i,t-2} + \sigma_3\Delta uc_{i,t-3} + \emptyset_0\left[\frac{CF_{it}}{K_{i,t-1}}\right] + \emptyset_1\left[\frac{CF_{i,t-1}}{K_{i,t-2}}\right] + \emptyset_2\left[\frac{CF_{i,t-2}}{K_{i,t-3}}\right] + \emptyset_3\left[\frac{CF_{i,t-3}}{K_{i,t-4}}\right] + \gamma_t + \eta_i + \vartheta_{it} \quad (8)$$

Where $\gamma_t + \eta_i + \vartheta_{it} = \epsilon_{it}$. Error term consists of the unobservable firm specific effect ($\eta_i$) and unobservable time-specific effects ($\gamma_t$). $\vartheta_{it}$ is the remainder stochastic disturbance term, which is independently and identically distributed (i.i.d).

### 3.3 Derivation of capital stock

The construction of capital stock series in real terms has received a lot of attention, yet there is no consensus about a unique measure of real capital. Several theoretical and empirical problems are involved in measuring capital stock. Goldar (1986) provides a very useful review of both the conceptual problems and the shortcomings of the various existing estimates of capital stock for Indian manufacturing. Banerjee’s (1975) study, while using an appropriate deflator for capital goods prices, is based on an arbitrary assumption for obtaining base year capital stock. Hashim & Dadi's (1973) study represents a significant improvement over earlier studies. In particular, they have paid close attention towards obtaining the base year capital stock. The limitation, however, is in the capital goods deflator used—the use of price index of manufactured articles rather than a price index based on machinery and construction prices.

For the purpose of the present study, the real value of capital stock at replacement cost is constructed using Perpetual Inventory Method. CMIE’s Prowess database makes available the data on gross block (at historical cost), net block and annual depreciation of different firms in various years. The computation of real capital stock basically involves three steps:

(i) Construction of benchmark estimates for 2000-01.

(ii) Computation of real gross investment in different years from 2000-01 to 2014-15.

(iii) Computation of the capital stock for the period 2000-01 to 2014-15 by the perpetual inventory method, based on the benchmark estimate for 2000-01, yearly real investments and depreciation.

As a first step, the revaluation factor for computing the benchmark capital stock has been estimated. To do so, the methodology proposed by Srivastava (1996) has been used, which basically converts data on gross block for 2000–01 of different firms (which are at historic costs) to the replacement value of capital stock. The revaluation factor (R) has been computed which is applied to the capital stock in 2000-01 using the following formula:

$$R = \left[\frac{(1+g)(1+\pi) - (1+d)}{(g+\delta)(1+\pi)}\right] * \frac{(1-d)}{(1-\delta)}$$

In this formula, d represents the accounting rate of depreciation, g is the real fixed investment growth rate, $\pi$ is the growth rate in the price of capital goods and $\delta$ is the rate of economic depreciation. To compute the rate of accounting depreciation (d), the value of annual depreciation reported in the balance sheets of firms is divided by the net block. The ratio is calculated for each year between 2000-01 and 2014-15 and then an average is taken, which gives us the value of accounting depreciation. This computation has been done for each firm individually and hence its value will vary from firm to firm. The economic deprecation rate (δ) has been taken as constant at 5 per cent, across all the firms and across the years.

Next, the time-series data on gross fixed capital formation in registered manufacturing at current and constant prices (at 2004–05 base year) for the period 1980–81 to 2014–15 from National Accounts Statistics (CSO) has been used and the implicit deflator for fixed capital formation has been derived, which is treated as price index of capital goods (denoted by G). Then, the compound (annual) growth rate in the price index G between the years 1980–81 and 2000–01 has been taken as an estimate of the parameter π to be used in the formula for revaluation factor given above. In a similar way, the parameter g is computed. An exponential growth equation has been fitted to the previously mentioned real gross fixed capital formation series for registered manufacturing (denoted by S) for the period 1980–81 to 2000–01 (i.e. the equation $\ln S = \alpha + \theta t$ is fitted to the time series data on S where t denoted time and α and θ are parameters to be estimated). The estimated growth rate (θ) given by the fitted growth equation is taken to as an estimate of g for the equation for revaluation factor given above. For a firm that was set up after 1985–86, a shorter period is considered for deriving estimates of π and g. Thus, if a firm was set up in 1990–91, the growth rate in the price index of capital goods for the period 1991–92 to 2003–04 has been taken as the estimate of π. Similarly, the growth equation is fitted to the investment series for the period 1991–92 to 2003–04 to obtain an estimate of g.

The revaluation factor in the above formula revalues capital stock existing at the end of 2000–01. This transforms the value of assets form historical prices to current prices of 2000–01. A further price adjustment has been done to express the value of capital stock at 2014–15 prices. This is based on the implicit deflator for gross fixed capital formation mentioned above.

The perpetual inventory method is then used to calculate capital stock in different firms from the years 2000–01 to 2014–15. To the benchmark year estimate, i.e. the estimate for 2000–01, annual real investment (calculated as difference in net block) is added and annual depreciation at the rate of 5 per cent is deducted. To explain the procedure, by adding real investment of 2001–02 to the benchmark estimate for 2000–01 and allowing for 5 per cent depreciation on the value of capital stock at the end of 2000–01, the capital stock for 2001–02 is obtained. This process is continued till the estimates for 2014–15 are obtained.

### 3.4 Derivation of user cost of capital

Neoclassical model says that any change in monetary policy stance through variations in interest rate will affect the user cost of capital. A monetary expansion policy through a decline in interest rate will decrease the firm's user cost of capital and vice versa. Hence, it can be concluded that the importance of interest rate channel in monetary policy transmission mechanism can be examined through the firm's user cost of capital. Most of the studies follow Hall & Jorgenson (1967) methodology for the derivation of user cost of capital. Following Nagahata & Sekine (2005), user cost of capital can be expressed as follows:

$$UC_{it} = \frac{p_{i,t}^{k}}{p_{i,t}} \frac{\left(r_t + \delta_{i,t} - \dot{p}_{i,t}^{k}\right)(1 - \tau_t \mu_{i,t})}{(1 - \tau_{i,t})}$$

Where $p^k_{i,t}$ is the price of capital goods which has been proxied by de-trended WPI index of machinery & transport equipment, $\dot{p}^k_{i,t}$ is its rate of change, $p_{i,t}$ is the price of final goods which has been proxied by de-trended WPI index, $r_t$ is yield on 10-year G-sec, $\tau_{i,t}$ is the rate of corporate tax in India[6] , $\mu_{i,t}$ is the depreciation allowance[7] and $\delta_{i,t}$ is the firm specific rate of economic depreciation[8].

### 3.5 Examining the short-run effects of interest rate and credit channels

The presence of the user cost of capital growth ($uc$) and cash flow to capital stock ratio $\left[\frac{CF_{it}}{K_{i,t-1}}\right]$ in equation (8) enables that the impact of both interest rate and credit channel on investment spending of firms could be examined. For the derivation of user cost of capital, see Appendix 2. In particular, the short-run effects of interest rate channel can be analysed by checking the signs and significance of the coefficients of the user cost of capital, i.e. $\sigma_0, \sigma_1, \sigma_2 \text{ and } \sigma_3$ . The sign for their sum of coefficients is expected to be negative as an increase in interest rates will increase the user cost of capital and subsequently decrease firms' investment spending. Similarly, the short-run effects of the credit channel can be checked by seeing the coefficients $\emptyset_0, \emptyset_1, \emptyset_2 \text{ and } \emptyset_3$ .

## 4. Methodology and Data Selection

The analysis for this study is based on the Prowess data that is maintained by the Centre for the Monitoring of the Indian Economy (CMIE), and is the most comprehensive source of financial

[6] Corporate tax rate inclusive of the surcharge.

[7] Following Hoshi-Kashyap (1990), $\mu_t$ is defined as $\mu_t = \frac{\delta(1+r_t)}{r_t+\delta}$, where δ is depreciation over capital stock ratio and $r_t$ is 10-year G-sec yield.

[8] Assuming that firms' use straight-line depreciation, the depreciation rate $\delta_t = 2/L_t$, it can be shown using Salinger and Summers (1983) that $L_t = GFA_t/DEP_t$ , where $GFA_t$ = gross fixed assets during time t and $DEP_t$ is the accounting depreciation during time t .

information on individual firms in India. For estimation purpose, annual balanced panel data of manufacturing firms for the period 2000-01–2013-14 is used[9]. *We start with a total of 22501 observations for 1612 companies for our baseline estimation.* Summary statistics of the main variables is given in Table: 1. As we can see from the data the maximum and minimum value of cash flow to capital stock and investment to capital stock suggest presence of possible outliers. There is a possibility of distressed firms also in our sample and we explain this in more details in analysis section.

**Table 1: Summary Statistics of Variables Used in the Study**

| Variable | Observations | Mean | Std. Dev | Min | Max |
|---|---|---|---|---|---|
| Log of sales | 21,955 | 6.76 | 1.87 | -2.74 | 14.87 |
| User cost of capital stock | 22,482 | 0.13 | 0.03 | 0.05 | 0.48 |
| Cash flow to Capital stock | 20,889 | 0.18 | 0.63 | -13.73 | 43.75 |
| Investment to Capital stock | 20,889 | 0.17 | 1.02 | -2.83 | 123.79 |

The inclusion of the lagged dependent variables in the baseline model (equation 8) implies that there is correlation between the regressors and the error term since the lag of the investment ratio $\left\lfloor\frac{I_{i,t-1}}{K_{i,t-2}}\right\rfloor$ depends on the error term $(\in_{i,t-1})$ which is a function of the firm specific effect $(\eta_i)$ and time-specific effect $(\gamma_t)$. The lagged dependent variable attempts to capture the effects of delays in expectation building, investment decisions and the installation of capital goods. Hence, for empirical purpose, we have estimated the model using System and Difference Generalised Method of Moments (GMM). One of the main advantages of using GMM is that it selects the instruments itself in order to solve the endogeneity problem of the system.

[9] We drop the data for year 2014-15 because we get abnormally very high value of apparent interest rate (interest expense in period t/ (Debt in period t+ Debt in Period in t-1)) for large firms.

## 5. Empirical Results

In this section, empirical results are presented by estimating the baseline augmented dynamic neoclassical investment model as depicted in equation (8). The main results using both one-step System and Difference GMM are discussed. The main focus of the results is to show the importance of interest rate and credit channel in firm-level investment spending for the whole sample and sub-sample analysis of categorization into small and large firms.

### 5.1 Evidence on Interest Rate Channel:

The full sample estimation gives the results on the expected lines. It is interesting to observe that both one-step System GMM (Model 1) and Difference GMM (Model 2) give similar results. There is evidence of persistence of ratio of investment and past investment to capital significantly affecting the current investment to capital ratio. As estimates of Model 1 in Table 2 shows, the contemporaneous coefficient of user cost of capital growth is negative and statistically significant in influencing firm-level investment spending. The magnitude of the contemporaneous coefficient is -0.0775 which implies that one per cent increase in the user cost of capital growth leads to a decline in the investment to capital ratio by 7.75 per cent (growth rate of user cost of capital has been defined in per cent, whereas all other ratios and growth rates are not in per cent terms). The total coefficient of user cost of capital growth is negative and statistically significant as well. Thus, the results show that there is both negative and significant impact of user cost of capital growth on firm's investment spending, thus supporting the relevance of the interest rate channel in influencing firm-level investment spending.

Further, as results of Model 1 show, the contemporaneous coefficient of cash flow to capital stock ratio is positive but not statistically significant. But the lag 2 coefficient of cash flow to capital stock ratio is positive and statistically significant. The total coefficient of cash flow to capital stock ratio is also positive and statistically significant. The results from Model 2 are also on similar lines as that of estimates of Model 1. The significance of the cash flow to capital stock ratio thus supports the importance of credit channel in influencing firm-level investment spending.

The estimates of both Models 1 and 2 in Table 2 show that sales growth too plays an important role in influencing the firm-level investment spending as the contemporaneous coefficients of sales growth in both the models are positive and statistically significant. Thus, the statistically significant effect of sales growth indicates the relevance of financial accelerator effect in affecting investment spending of firms. However, the rest of the lags of sales growth are negative and statistically insignificant in both the models but the total coefficient on sales remains positive.

**Table 2: GMM Estimates of Investment Capital Ratio: Baseline**

| Independent Variables | Model 1: System GMM | | Model 2: Difference GMM | |
|---|---|---|---|---|
| | Coefficient | Robust SE | Coefficient | Robust SE |
| $(I_{t-1}/K_{t-2})$ | 0.0479** | (3.24) | 0.0385** | (2.88) |
| $(I_{t-2}/K_{t-3})$ | 0.0292* | (2.51) | 0.0204* | (1.98) |
| $(I_{t-3}/K_{t-4})$ | 0.0318* | (2.48) | 0.0276* | (2.28) |
| $\Delta logUCC_{t}$ | -0.0775*** | (-6.62) | -0.0767*** | (-6.61) |
| $\Delta logUCC_{t-1}$ | -0.0187*** | (-5.76) | -0.0187*** | (-5.79) |
| $\Delta logUCC_{t-2}$ | -0.00532 | (-1.90) | -0.00527 | (-1.88) |
| $\Delta logUCC_{t-3}$ | -0.00398 | (-1.52) | -0.00414 | (-1.60) |
| $(CF_{t}/K_{t-1})$ | 0.123 | (1.91) | 0.123 | (1.90) |
| $(CF_{t-1}/K_{t-2})$ | 0.0683 | (1.54) | 0.0695 | (1.53) |
| $(CF_{t-2}/K_{t-3})$ | 0.144*** | (3.53) | 0.144*** | (3.63) |
| $(CF_{t-3}/K_{t-4})$ | 0.0324 | (0.56) | 0.0316 | (0.55) |
| $\Delta logSales_{t}$ | 0.178*** | (3.70) | 0.180*** | (3.73) |
| $\Delta logSales_{t-1}$ | -0.0281 | (-1.29) | -0.0258 | (-1.20) |
| $\Delta logSales_{t-2}$ | -0.0290 | (-1.07) | -0.0258 | (-0.97) |
| $\Delta logSales_{t-3}$ | -0.0380 | (-1.20) | -0.0348 | (-1.11) |
| Constant | 0.122*** | (4.72) | 0.125*** | (4.73) |
| No of Observation | 14081 | | 15653 | |
| No of Companies | 1571 | | 1572 | |

*t* statistics in parentheses $^{*}$ $p < 0.05$, $^{**}$ $p < 0.01$, $^{***}$ $p < 0.001$
**Note:** The dependent variable is the firm-level investment spending measured by the ratio of capital expenditure to lagged capital stock.

One can derive the expression of long run effect of a unit change in cash flow to capital ratio as follows:

$$\frac{\emptyset_0 + \emptyset_1 + \emptyset_2 + \emptyset_3}{1 - \alpha_1 - \alpha_2 - \alpha_3}$$

Similarly, the long run effect of one percentage change in user cost of capital is expressed as:

$$\frac{\sigma_0 + \sigma_1 + \sigma_2 + \sigma_3}{1 - \alpha_1 - \alpha_2 - \alpha_3}$$

Finally, the long run effect of one percentage change in sales growth is expressed as:

$$\frac{\theta_0 + \theta_1 + \theta_2 + \theta_3}{1 - \alpha_1 - \alpha_2 - \alpha_3}$$

As one can see from the above expressions, the long run effects depends upon the sum of contemporaneous and lag coefficient and as long as the sum is positive, the long run effect is positive. Conversely, if the sum is negative the long run effect is negative as well.

**Table 3: Long Run Impact**

| | **System GMM** | **Difference GMM** |
|---|---|---|
| $\sigma_0 + \sigma_1 + \sigma_2 + \sigma_3$ | -0.11 | -0.10 |
| $\emptyset_0 + \emptyset_1 + \emptyset_2 + \emptyset_3$ | 0.37 | 0.37 |
| $\theta_0 + \theta_1 + \theta_2 + \theta_3$ | 0.08 | 0.09 |
| $1 - \alpha_1 - \alpha_2 - \alpha_3$ | 0.89 | 0.91 |
| Long Run Effect of User cost | -0.12 | -0.11 |
| Long Run Effect of Cash Flow | 0.41 | 0.40 |
| Long Run Effect of Sales | 0.09 | 0.10 |

The Wald test on joint significance suggest that $\sigma_0 + \sigma_1 + \sigma_2 + \sigma_3$ , $\emptyset_0 + \emptyset_1 + \emptyset_2 + \emptyset_3$ and is $\alpha_1 + \alpha_2 + \alpha_3$ is statistically significant and therefore we use these to estimate long run impact as explained above. Our estimates suggest that one per cent increase in the user cost of capital growth leads to a decline in the investment to capital ratio by 12.00 per cent in the long run. Similarly, if cash flow to capital ratio increase by one unit then that leads to 0.37 unit increase in the investment to capital ratio in the long run. Since the joint significance suggest that $\theta_0 + \theta_1 + \theta_2 + \theta_3$ is not statistically significant, we can say that sales growth has no long run impact on investment to capital ratio.

In summary, the results for the full sample from Models 1 and 2 suggests that user cost of capital growth, cash flow to capital stock ratio, and sales growth plays an important role in influencing firm-level investment spending in the short run whereas in the long run, user cost of capital growth and cash flow to capital stock ratio significantly affect the investment to capital ratio. Further, the statistical significance and expected sign of total coefficients of user cost of capital growth and cash flow to capital stock ratio illustrate the significance of interest rate and credit channels in influencing the investment spending of firms in India both in the short as well as in the long run.

### 5.2 Robustness Check

There is a possibility that our results above are driven by distressed firms or outliers. Outliers could be in terms of size, cash flow to capital and investment to capital. In this section we try to eliminate the possible effects of all these one by one. *At this point we would like to clarify that our elimination of outlier effects on the basis of cash flow to capital and investment to capital ratio is also likely to remove distressed firms from our sample because distressed firms are likely to have very low values of these ratios too*.

First we classify all those firm which have three consecutive years of negative investment as distressed firms and we drop them. We are left with now 1479 firms. We estimate the model with data on 1479 firms and the results from the same is given in table 4 in appendix 2. The estimates are similar to the results obtained for full sample and we can say that our results are not being driven by the distressed firms in our samples. Distressed samples may have negative investment because of their structural reasons and we may attribute the effect to user cost and if the effect of distressed firms dominates we may have overall effects for user cost when none exist.

We provide addition robustness by dropping all the observation beyond 2 standard deviation of the log total assets. This allows us to correct for possible distortion in estimates caused due to very large and very small firms. This corrects for outliers due to size as the estimate may be driven by the behavior of very large and very small firms.

The results given in Table 5 in appendix 2 are very similar to our baseline estimates. Even after removing the possible outliers on the basis of size we have evidence of interest rate and credit channel of monetary transmission. As mentioned in the table 1 we have firms with very high and low values for investment to capital and cash flow to capital ratios. These are also firms likely to be financially distressed. Therefore, we do estimations after removing outliers for cash flow to capital and investment to capital ratios and the results for the same are given in table 6 and table 7 respectively.

As we can see from table 6 in appendix 2 the estimates obtained from the removing outliers on the basis of cash flow to capital ratio continues to support the evidence on interest rate channel of monetary transmission. Not only that but also our evidence on credit channel of monetary transmission gets stronger. Earlier the contemporaneous coefficient on the cash flow to capital ratio was not small and not statistically significant. Now it is relatively large and significant, suggesting a strong credit channel for monetary transmission.

Finally, we report the results obtained from removing the outliers on the basis investment to capital ratio in table 7 in appendix 2. The estimates are similar to the baseline model. There is evidence of presence of interest rate and credit channels of monetary transmission as was in the case of baseline model. In-fact, the evidence on credit channel becomes stronger and the persistence of lagged investment increases which are on expected lines.

The results reported in this section provides robustness to our evidence of working of interest rate and credit channel of monetary transmission. Our robustness exercise suggest that the evidence is not driven by the possible inclusion of distressed firms and outlier observations in our sample.

### 5.2.1 Sub-sample estimates: Removing financially Constrained Firms and Size Effect in Cash Flow Sensitivity

We estimate a variant of equation 8, where we omit contemporaneous cash flow to capital ratio

$$\left[\frac{I_{it}}{K_{i,t-1}}\right] = \alpha_1 \left[\frac{I_{i,t-1}}{K_{i,t-2}}\right] + \alpha_2 \left[\frac{I_{i,t-2}}{K_{i,t-3}}\right] + \alpha_3 \left[\frac{I_{i,t-3}}{K_{i,t-4}}\right] + \theta_0 \Delta y_{it} + \theta_1 \Delta y_{i,t-1} + \theta_2 \Delta y_{i,t-2} + \theta_3 \Delta y_{i,t-3} +$$

$$\sigma_0 \Delta uc_{it} + \sigma_1 \Delta uc_{i,t-1} + \sigma_2 \Delta uc_{i,t-2} + \sigma_3 \Delta uc_{i,t-3} + \epsilon_{it} \quad (8')$$

The error term from this regression, is used to construct a measure that assesses a firm's investment-cash flow sensitivity. In particular, if a firm's investment is not influenced by its cash flows, then average error in high-cash-flow periods should not be significantly different from average error in low cash flow period. The immediate implication of this is that average of errors weighted by cash flow to capital ratio should not be different from un-weighted average. Therefore, we expect the difference between weighted and un-weighted average to be zero. We define cash flow sensitivity as

$$CFS = \sum_{t=1}^{T} \left( \frac{\frac{CF_t}{\mathrm{K_{t-1}}} \epsilon_{it}}{\sum_{t=1}^{T} \frac{CF_t}{\mathrm{K_{t-1}}}} \right) - \frac{1}{T} \sum_{t=1}^{T} \epsilon_{it}$$

Firms having positive value of this difference have investment sensitive to cash flow and can be termed as financially constrained. We drop these firms from the sample and estimate equation 8 again. Estimated results suggest that the interest rate channel of monetary transmission that we have shown above is not driven by the financially constrained firms because even if we remove the financially constrained firms we have the negative impact of user cost of capital. We do not report this result but we use this classification to document the characteristics of the different types of firms on the basis of investment cash flow sensitivity. For this we make three groups of investment cash flow sensitivity on the basis of this error term. First group with mean CFS of -.0760193 is terms firms having negative investment cash flow sensitivity (NFS). Second group with mean .0098895 is termed as cash flow insensitive (IS). Third group with mean .1005523 is termed as positive cash flow sensitivity (PFS) and these are likely financially constrained firms. We leave the insensitive group and document the differences in characteristics of negative and positive cash flow sensitive firms. We do two sample t test to test for mean differences. Results suggest that NFS firms are larger in size and has higher capital stock as well as gross fixed assets. The NFS firms have lower debt equity ratio but the difference is not statistically significant. The NFS firms have higher profitability also. Our results reinforce the size effect that has been documented in the literature as well and suggests that small firms are likely to have higher investment to cash flow sensitivity.

## 6. Conclusion

This study estimates the dynamic panel version of augmented neoclassical investment model using ARDL specification. The results provide support for interest rate and credit channels in transmitting to firm-level investment spending in India. Our evidence of interest rate channel is robust and is not driven by the presence of outliers, financially distressed and financially constrained firms. Using the method of Hovakimian (2009), we show that small firms show higher sensitivity with respect to cash flow. The heterogeneous impact of cash flow to capital stock ratio on investment spending of small and large firms provides further evidence in favor of working of broad credit channel of monetary transmission in India. The study of micro data in case of India has distinct advantages in terms of its ability to provide useful insights into the determinants of firm-level investment spending with a special emphasis on the role of interest rate and credit channel in influencing the same.

There are several important implications of the results obtained in this study for the implementation of monetary policy in India. Firstly, the importance of interest rate channel in influencing firm-level investment implies that the Central Bank through changes in its policy rate has a greater chance of stabilizing investment. Hence, in times of subdued performance by firm-level investment spending, Central Bank by lowering its interest rates could boost the investment levels. Secondly, since credit channel of monetary policy transmission affects the investment spending of small firms relatively more than that of the large firms, the Central Bank needs to ensure that the domestic liquidity conditions support the growth of the small firms. Additionally, the Central Bank needs to monitor the microeconomic indicators of the small firms closely while formulating its monetary policy.

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## Appendix 1: Derivation of Neoclassical Demand for Capital

Assuming that under Constant Elasticity of Substitution (CES), the neoclassical production function can be written as:

$$F\ (L_{it}, K_{it}) = TFP_i A_t\ \left[\beta_i\ L_{it}\ ^{\frac{\sigma-1}{\sigma}} + \ \alpha_i\ K_{it}\ ^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}\upsilon} \quad \text{(a)}$$

The first order condition for a firm's optimisation problem leads to the equality between the marginal product of capital ($F_k$) and the user cost of capital ($UC_{it}$) as follows:

$$F_K(L_{it}, K_{it}) = UC_{it} \quad \text{(b)}$$

By substituting, Equation (b) into Equation (a), the first order condition of firm profit maximisation is as follows

$$\upsilon\alpha_i\ K_{it}\ ^{\frac{-1}{\sigma}}\ TFP_i\ A_t\left[\beta_i\ L_{it}\ ^{\frac{\sigma-1}{\sigma}} + \ \alpha_i\ K_{it}\ ^{\frac{\sigma-1}{\sigma}}\right]^{(\frac{\sigma}{\sigma-1}\upsilon)-1} = UC_{it} \quad \text{(c)}$$

Equation (c) could be modified as:

$$\upsilon\alpha_i\ K_{it}\ ^{\frac{-1}{\sigma}} \frac{TFP_i A_t\left[\beta_i\ L_{it}\ ^{\frac{\sigma-1}{\sigma}} + \alpha_i\ K_{it}\ ^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}\upsilon}}{\left[\beta_i\ L_{it}\ ^{\frac{\sigma-1}{\sigma}} + \alpha_i\ K_{it}\ ^{\frac{\sigma-1}{\sigma}}\right]} = UC_{it} \quad \text{(d)}$$

Let $Y_{it} = TFP_i\ A_t\left[\beta_i\ L_{it}\ ^{\frac{\sigma-1}{\sigma}} + \ \alpha_i\ K_{it}\ ^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}\upsilon}$

$$\left[\frac{Y_{it}}{TFP_i\ A_t}\right] = \ \left[\beta_i\ L_{it}\ ^{\frac{\sigma-1}{\sigma}} + \ \alpha_i\ K_{it}\ ^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}\upsilon} \quad \text{(e)}$$

Raising the power of both sides of Equation (e) by $\frac{\sigma-1}{\sigma\upsilon}$

$$\left[\frac{Y_{it}}{TFP_i\ A_t}\right]^{\frac{\sigma-1}{\sigma\upsilon}} = \ \left[\beta_i\ L_{it}\ ^{\frac{\sigma-1}{\sigma}} + \ \alpha_i\ K_{it}\ ^{\frac{\sigma-1}{\sigma}}\right] \quad \text{(f)}$$

Now substituting Equation (f) in Equation (d), the following is obtained

$$\frac{TFP_i\,A_t\left[\frac{Y_{it}}{TFP_i\,A_t}^{\frac{\sigma-1}{\sigma\upsilon}}\right]^{\frac{\sigma}{\sigma-1}\upsilon}}{\left[\frac{Y_{it}}{TFP_i\,A_t}\right]^{\frac{\sigma-1}{\sigma\upsilon}}}\upsilon\alpha_i\,K_{it}{}^{\frac{-1}{\sigma}} = UC_{it} \qquad \text{(g)}$$

By re-arranging Equation (g), following equation is obtained

$$\frac{Y_{it}\upsilon\alpha_i\,K_{it}{}^{\frac{-1}{\sigma}}}{\left[\frac{Y_{it}}{TFP_i\,A_t}\right]^{\frac{\sigma-1}{\sigma\upsilon}}} = UC_{it} \qquad \text{(h)}$$

By re-arranging Equation (h), following equation is obtained

$$Y_{it}^{1-\left(\frac{\sigma-1}{\sigma\upsilon}\right)}\left[\frac{1}{TFP_iA_t}\right]^{-\left(\frac{\sigma-1}{\sigma\upsilon}\right)}\ \upsilon\alpha_i\,K_{it}{}^{\frac{-1}{\sigma}} = UC_{it} \qquad \text{(i)}$$

Taking log on both sides of Equation (i)

$$\left(1-\frac{\sigma-1}{\sigma\upsilon}\right)logY_{it} + \log[(TFP_iA_t)^{\frac{\sigma-1}{\sigma\upsilon}}\upsilon\alpha_i]\ (-\frac{1}{\sigma}logK_{it}) = \log UC_{it}$$

Multiplying by σ on the both sides

$$\left(\frac{\sigma\upsilon-\sigma+1}{\upsilon}\right)logY_{it} + log\left[TFP_iA_t{}^{\frac{\sigma-1}{\sigma\upsilon}}\ (\upsilon\alpha_i)^{\sigma}\right](-logK_{it}) = \sigma logUC_{it}$$

Or $\sigma uc_{it} = \theta y_{it} + h_{it} - k_{it}$ (j)

Where

$$\theta = \left(\frac{\sigma\upsilon-\sigma+1}{\upsilon}\right)$$

$k_{it}$ = log of capital stock

$y_{it}$ = log of output or sales

$uc_{it}$ = log of user cost of capital

$h_{it}$= $log\left[TFP_iA_t{}^{\frac{\sigma-1}{\sigma\upsilon}}\ (\upsilon\alpha_i)^{\sigma}\right]$ is the log of total factor productivity (TFP)

Equation (j) can be re-arranged to be re-written as

$$k_{it} = \theta y_{it} - \sigma uc_{it} + h_{it}$$

## Appendix 2: Results

**Table 4: GMM Estimates of Investment Capital Ratio: After Removing Firms with Three Consecutive Years of Negative Investment**

| Independent Variables | Model 1: System GMM | | Model 2: Difference GMM | |
|---|---|---|---|---|
| | Coefficient | Robust SE | Coefficient | Robust SE |
| $(I_{t-1}/K_{t-2})$ | 0.0454** | (2.97) | 0.0327* | (2.45) |
| $(I_{t-2}/K_{t-3})$ | 0.0286* | (2.42) | 0.0172 | (1.75) |
| $(I_{t-3}/K_{t-4})$ | 0.0322* | (2.43) | 0.0265* | (2.19) |
| $\Delta logUCC_t$ | -0.0770*** | (-6.22) | -0.0760*** | (-6.21) |
| $\Delta logUCC_{t-1}$ | -0.0191*** | (-5.51) | -0.0192*** | (-5.55) |
| $\Delta logUCC_{t-2}$ | -0.00497 | (-1.68) | -0.00493 | (-1.66) |
| $\Delta logUCC_{t-3}$ | -0.00379 | (-1.33) | -0.00404 | (-1.45) |
| $(CF_t/K_{t-1})$ | 0.119 | (1.88) | 0.118 | (1.86) |
| $(CF_{t-1}/K_{t-2})$ | 0.0686 | (1.53) | 0.0705 | (1.52) |
| $(CF_{t-2}/K_{t-3})$ | 0.145*** | (3.49) | 0.145*** | (3.59) |
| $(CF_{t-3}/K_{t-4})$ | 0.0326 | (0.56) | 0.0318 | (0.55) |
| $\Delta logSales_t$ | 0.189*** | (3.46) | 0.191*** | (3.50) |
| $\Delta logSales_{t-1}$ | -0.0304 | (-1.24) | -0.0274 | (-1.14) |
| $\Delta logSales_{t-2}$ | -0.0367 | (-1.19) | -0.0323 | (-1.08) |
| $\Delta logSales_{t-3}$ | -0.0466 | (-1.31) | -0.0426 | (-1.22) |
| Constant | 0.129*** | (4.75) | 0.133*** | (4.79) |
| No of Observation | 12990 | | 14439 | |
| No of Companies | 1448 | | 1449 | |

*t* statistics in parentheses * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

**Note:** We remove all firms which have consecutive three years of negative investment to capital ratio. The dependent variable is the firm-level investment spending measured by the ratio of capital expenditure to lagged capital stock.

**Table 5: GMM Estimates GMM Estimates of Investment Capital Ratio: Corrected for Size Outliers**

| Independent Variables | Model 1: System GMM | | Model 2: Difference GMM | |
|---|---|---|---|---|
| | Coefficient | Robust SE | Coefficient | Robust SE |
| $(I_{t-1}/K_{t-2})$ | 0.0478** | (3.04) | 0.0396** | (2.67) |
| $(I_{t-2}/K_{t-3})$ | 0.0282* | (2.31) | 0.0207 | (1.83) |
| $(I_{t-3}/K_{t-4})$ | 0.0252* | (2.02) | 0.0219 | (1.82) |
| $\Delta logUCC_t$ | -0.0782*** | (-6.39) | -0.0775*** | (-6.39) |
| $\Delta logUCC_{t-1}$ | -0.0184*** | (-5.47) | -0.0180*** | (-5.37) |
| $\Delta logUCC_{t-2}$ | -0.00515 | (-1.79) | -0.00508 | (-1.76) |
| $\Delta logUCC_{t-3}$ | -0.00401 | (-1.58) | -0.00410 | (-1.60) |
| $(CF_t/K_{t-1})$ | 0.129 | (1.84) | 0.128 | (1.82) |
| $(CF_{t-1}/K_{t-2})$ | 0.0697 | (1.45) | 0.0698 | (1.43) |
| $(CF_{t-2}/K_{t-3})$ | 0.143*** | (3.68) | 0.143*** | (3.76) |
| $(CF_{t-3}/K_{t-4})$ | 0.0325 | (0.55) | 0.0302 | (0.52) |
| $\Delta logSales_t$ | 0.139*** | (5.08) | 0.140*** | (5.14) |
| $\Delta logSales_{t-1}$ | -0.0270 | (-1.19) | -0.0239 | (-1.07) |
| $\Delta logSales_{t-2}$ | -0.0158 | (-0.67) | -0.0132 | (-0.57) |
| $\Delta logSales_{t-3}$ | -0.0197 | (-0.79) | -0.0163 | (-0.66) |
| Constant | 0.124*** | (4.64) | 0.127*** | (4.65) |
| No of Observation | 13306 | | 14850 | |
| No of Companies | 1535 | | 1541 | |

**Table 6: GMM Estimates GMM Estimates of Investment Capital Ratio: Corrected for Cash Flow to Capital Ratio Outliers**

| Independent Variables | Model 1: System GMM | | Model 2: Difference GMM | |
|---|---|---|---|---|
| | Coefficient | Robust SE | Coefficient | Robust SE |
| $(I_{t-1}/K_{t-2})$ | $0.0462^{***}$ | (4.00) | $0.0406^{***}$ | (3.69) |
| $(I_{t-2}/K_{t-3})$ | $0.0266^{**}$ | (2.66) | $0.0225^{*}$ | (2.37) |
| $(I_{t-3}/K_{t-4})$ | 0.0216 | (1.91) | 0.0197 | (1.72) |
| $\Delta logUCC_t$ | $-0.0786^{***}$ | (-8.53) | $-0.0780^{***}$ | (-8.55) |
| $\Delta logUCC_{t-1}$ | $-0.0233^{***}$ | (-7.50) | $-0.0232^{***}$ | (-7.50) |
| $\Delta logUCC_{t-2}$ | $-0.0110^{***}$ | (-4.58) | $-0.0110^{***}$ | (-4.59) |
| $\Delta logUCC_{t-3}$ | $-0.00524^{*}$ | (-2.47) | $-0.00522^{*}$ | (-2.47) |
| $(CF_t/K_{t-1})$ | $0.786^{***}$ | (7.01) | $0.782^{***}$ | (6.98) |
| $(CF_{t-1}/K_{t-2})$ | $0.126^{**}$ | (2.90) | $0.131^{**}$ | (3.00) |
| $(CF_{t-2}/K_{t-3})$ | $0.104^{*}$ | (2.21) | $0.106^{*}$ | (2.26) |
| $(CF_{t-3}/K_{t-4})$ | 0.0294 | (0.65) | 0.0300 | (0.66) |
| $\Delta logSales_t$ | $0.0965^{*}$ | (1.98) | $0.0975^{*}$ | (2.01) |
| $\Delta logSales_{t-1}$ | $-0.0791^{**}$ | (-3.26) | $-0.0781^{**}$ | (-3.27) |
| $\Delta logSales_{t-2}$ | -0.0455 | (-1.62) | -0.0456 | (-1.64) |
| $\Delta logSales_{t-3}$ | -0.0516 | (-1.60) | -0.0510 | (-1.59) |
| Constant | 0.00915 | (0.53) | 0.0101 | (0.58) |
| No of Observation | 13506 | | 15105 | |
| No of Companies | 1559 | | 1565 | |

*t* statistics in parentheses $^{*}$ $p < 0.05$, $^{**}$ $p < 0.01$, $^{***}$ $p < 0.001$

**Note:** The dependent variable is the firm-level investment spending measured by the ratio of capital expenditure to lagged capital stock.

**Table 7: GMM Estimates GMM Estimates of Investment Capital Ratio: Corrected for Investment to Capital Ratio Outliers**

| Independent Variables | Model 1: System GMM | | Model 2: Difference GMM | |
|---|---|---|---|---|
| | Coefficient | Robust SE | Coefficient | Robust SE |
| $(I_{t-1}/K_{t-2})$ | 0.160*** | (7.66) | 0.158*** | (8.47) |
| $(I_{t-2}/K_{t-3})$ | 0.0717*** | (4.18) | 0.0775*** | (4.39) |
| $(I_{t-3}/K_{t-4})$ | 0.0129 | (1.02) | 0.0135 | (1.11) |
| $\Delta logUCC_t$ | -0.0487*** | (-10.65) | -0.0485*** | (-10.64) |
| $\Delta logUCC_{t-1}$ | -0.0117*** | (-7.98) | -0.0117*** | (-7.82) |
| $\Delta logUCC_{t-2}$ | -0.00299* | (-2.09) | -0.00278 | (-1.92) |
| $\Delta logUCC_{t-3}$ | -0.000964 | (-0.66) | -0.000879 | (-0.60) |
| $(CF_t/K_{t-1})$ | 0.0851*** | (4.25) | 0.0842*** | (4.16) |
| $(CF_{t-1}/K_{t-2})$ | 0.0228 | (1.11) | 0.0198 | (1.00) |
| $(CF_{t-2}/K_{t-3})$ | 0.0140 | (1.05) | 0.0157 | (1.23) |
| $(CF_{t-3}/K_{t-4})$ | 0.00283 | (0.20) | 0.00139 | (0.10) |
| $\Delta logSales_t$ | 0.0983*** | (7.31) | 0.0994*** | (7.35) |
| $\Delta logSales_{t-1}$ | 0.0142 | (1.55) | 0.0159 | (1.72) |
| $\Delta logSales_{t-2}$ | 0.0247* | (2.39) | 0.0252* | (2.45) |
| $\Delta logSales_{t-3}$ | 0.0216* | (2.17) | 0.0225* | (2.26) |
| Constant | 0.105*** | (10.64) | 0.104*** | (10.25) |
| No of Observation | 13620 | | 15244 | |
| No of Companies | 1569 | | 1571 | |

*t* statistics in parentheses * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

**Note:** The dependent variable is the firm-level investment spending measured by the ratio of capital expenditure to lagged capital stock.