Q-Theory of Investment Revisited: Merton's q *

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ABSTRACT

We utilize an option pricing framework to construct a proxy for market value of a firm's physical assets, which is then used to estimate the marginal value of the firm's investment, denoted as q^{merton}. The proposed measure of marginal value of investment outperforms its alternatives in explaining dynamics of fixed asset investment by more than 71% during the period of 1985-2007 in the U.S. economy. Other conventional factors such as a firm's idiosyncratic volatility, real discount factor, the firm's book leverage, and its cash holdings that are documented to be associated with investment in prior literature lose their explanatory power once q^{merton} is included in a standard investment regression model. The findings suggest that the empirical underperformance of Q-Theory of Investment is subject to a measurement error problem in marginal value of investment, which can be alleviated by using a structural framework.

Keywords: Merton's Model; Tobin's Q; Fixed Investment.

JEL classification: E22; E44; G31.

I. Introduction

Investment decisions are related to future prosperity, and hence, economic agents are often evaluated by the results of such decisions. Since Tobin's [1969] seminal work first appeared in the literature, a significant amount of research has been devoted to understanding the investment choices of individuals. Specifically Tobin's argument relies on the idea that the rate of investment should be related to the benefit of such choices (i.e. market value of invested capital) with respect to their associated cost (i.e. replacement cost of invested capital). Related theoretical frameworks also have relied on this fundamental principal. For instance, Lucas and Prescott [1971] proposed a dynamic investment model with convex adjustment costs to capture the dynamics of investment. Abel [1979] showed that rate of investment, which is the pace of reaching optimal level of capital stock, is mainly driven by marginal value of investment. Hayashi [1982] equated marginal value of investment to its average value by assuming an investor is a price taker, and production and cost of installment of capital are both homogeneous.[1] Although marginal value of investment is not directly observable in data, one can test the predictions of underlying theory by constructing its corresponding proxy, $q^{average}$, under Hayashi's assumptions.

Empirical investigation of an investment model has failed to provide satisfactory subsequent results. Specifically $q^{average}$ was not powerful enough to explain investment dynamics, and residuals in standard regression models appeared to be correlated with other omitted factors, i.e. investor's financial prospects (Hasset and Hubbard [1996]; Caballero [1999]). In this paper, we intend to circumvent these potential shortcomings of underlying theory by providing an alternative approach to approximate the marginal value of investment.

In order to test the validity of the underlying theory of investment, first, we adopt the structural framework of Black and Scholes [1973] and Merton [1974] for pricing options and

[1] Hayashi [1982] defined marginal value of investment as the ratio of market value of an additional unit of capital to its replacement cost, whereas average value of investment as the market value of existing capital scaled by its replacement cost.

obtain a proxy for market value of a firm's assets in place. This approach is also commonly used by many academicians and practitioners to assess the credit worthiness of an economic entity. The model treats a firm's equity as a call option which is written on its underlying asset with a strike price of its outstanding debt. Since the model is designed to account for the firm's financial prosperity through its expected default probability, it provides a better measure of its market value than the conventional measures that are used in standard finance literature, such as the sum of book value of a firm's debt and market value of its outstanding equity as a proxy of its market value. Derived value of a firm's assets is then used to construct a new $q^{average}$ measure, denoted as q^{merton}. Given data availability, we test the implementation of Q-Theory of Investment and analyze the performance of q^{merton} against its alternatives, such as $q^{classic}$ by Hall [2001] and q^{bond} by Philippon [2009], in explaining investment dynamics during the time period from 1985 to 2007.[2]

According to our findings, q^{merton} accounts for approximately 71% variation in aggregate level of U.S. investment in physical assets. Several key components of other measures that are documented to be significantly related to investment level, such as idiosyncratic volatility, real discount factor, relative corporate bond prices, and a firm's cash holdings, are also found to lose their explanatory power at conventional statistical levels.[3] In addition, the aggregate level of book leverage, which is a function of corporate debt obligations, has unrobust statistical power to explain the aggregate level of investment after q^{merton} is controlled in empirical models.[4] In contrast to the findings of prior literature, we observe that idiosyncratic volatility and real discount factor are negatively associated with the aggregate level of investment at the 5%

[2]The findings are not observed to be time specific, since they are robust when we extend the sample to 2011 in untabulated results. These results are available upon request. Our analysis starts from 1985 in order to perform more comparable analysis to bond pricing literature, i.e. Eom, Helwege and Huang [2004].

[3]"In the short run, q^{bond} depends mostly on the relative price component. Year-to-year changes in $(\phi + r_t^{10})/(\phi + y_t^{Baa})$ account for 85% of the year-to-year changes in q^{bond}. In the long run, leverage, and especially, idiosyncratic volatility are also important." Page 1032 of Philippon [2009].

[4]q^{merton} is constructed by using publicly traded U.S. firms' accounting and market information, and hence does not reflect the prospects of private firms directly. Unfortunately, this is the caveat of using publicly available data from S&P's Compustat and CRSP merged data sample which reflects only the information about public firms. However, the effect of investment dynamics of private firms at the aggregate level is documented to be a relatively small portion of investment dynamics at macro level, i.e. correlation between investment measures of alternative investment measures are close to 74%.

significance level during the time period after 1985. Economically, our findings are also significantly valuable since one standard deviation increase in $q^{classic}$, q^{bond} and q^{merton} increases the aggregate level of investment by 8.03%, 7.03%, and 9.15% at its mean, respectively.

We trust the power of q^{merton} over the alternative factors in explaining investment embedded in its ability to capture the difference between market value of a firm's debt and its book value.[5] In fact, the results at the firm level analysis indicates that almost 71% of the explanatory power of q^{merton} comes from the sample of firms that have significant deviation between book value and market value of its debt. On average, these firms are either risky or they have high levels of debt in their capital structure. These results are also in agreement with the findings of bond pricing literature, which are designed to explain yield spreads (Jones, Mason and Rosenfeld [1984]; Eom, Helwege and Huang [2004]).[6]

We also observe that q^{merton} performs better in explaining investment rates when we restrict our sample to the firms that rely more heavily on tangible capital. Although when firms from these industries are also included in our sample, q^{merton}'s incremental explanatory power is still relatively higher than its alternatives, but drops by 20%. One potential explanation is that these firms rely more heavily on other type of inputs, i.e. intellectual properties rather than physical assets, to produce final output. Our findings are also robust in alternative specifications, such as extension of time period to post financial-crisis period, as well as the aggregate level of investment constructed from an alternative sample of firms.

Research design in this paper is in line with academic work that is motivated to address the potential failures of the underlying investment theory due to its corresponding assumptions. For instance, it is possible that some firms may not necessarily be price-takers or do not satisfy constant return to scale assumption on production functions. It is also possible that some

[5] It is common to use book value of debt as a proxy to construct $q^{average}$ in standard literature (Erickson and Whited[2006]).

[6] According to Jones, Mason and Rosenfeld [1984], and Eom, Helwege and Huang [2004], Merton's bond pricing model tends to over predict bond prices, and estimated errors in bond prices are higher for non-investment grade firms. However, the model works well for low-grade bonds since it has a greater incremental power to explain riskier bonds.

firms may not be facing convex cost functions (Dixit and Pindyck [1994]; Caballero and Engle [1999]). Alternatively, the financial prosperity of some other firms may play a role in their investment decisions (Bernanke and Gertler [1989]; Fazzari, Hubbard, and Petersen [2000]; Alti [2003]). Finally, measurement errors and aggregation biases in some of the main variables may empirically produce unsatisfactory results.

Except for the measurement errors most of these suspicions about the underlying theory are refuted by the findings in empirical literature. Specifically, Hall [2003] provided evidence of firms' price-taking behavior and constant returns to scale of production functions. A convex adjustment cost function assumption may still be a restrictive assumption at the firm level, but its impact is still inconclusive at the aggregate level (Thomas [2002]; Hall [2004]; Bachmann, Caballero and Engel [2006]). Gomes [2001] documented that financial constraints do not matter, and if there are no measurement error problems then $q^{average}$ should be a main factor to explain economic agents' investment choices. Hall [2004] showed that aggregation bias is not the main reason behind the failure of existing models. Measurement problems in some key components of investment models, however, might be the reason behind unsatisfactory results of Q Theory of Investment. For instance, Gilchrist and Himmelberg [1995], and Abel and Blanchard [1986] applied vector autoregression models (VAR) rather than conventional methods to construct $q^{average}$. Such measures can potentially capture investment-to-cash flow sensitivities. Cumins, Hasset, and Oliner [2006] used analyst forecast to estimate $q^{average}$, which can also potentially offset valuation errors in equity markets. Erikson and Whited ([2000]; [2006]) proposed a structural estimation framework, such as a generalized method of moments (GMM) estimators to cure some of the measurement problems that one can observe in data.[7]

In a similar context, our approach is more in line with Philippon [2009], who proposed an alternative proxy based on the information in bond markets, q^{bond}. The proposed measure is

[7] In untabulated results, we also analyze the magnitude of measurement errors in q^{merton} within the context of Erickson and Whited ([2000]; [2006]; [2010]). We find that q^{merton} is still subject to some level of measurement error, which is relatively small and negligible with respect to its alternatives at the disaggregated level.

motivated to capture the discrepancy of the mispricing between bond and equity markets, and hence, it managed to outperform $q^{classic}$ in explaining the investment rate between 1953-2007.[8] Although relative performance of q^{bond} against $q^{classic}$ measure decreased significantly after the 1980s, q^{bond}'s empirical power mainly comes from four underlying factors: real interest rate, firm's leverage, idiosyncratic volatility of a firm's equity, and relative price of corporate to treasury bonds. Although our paper deviates from Philippon [2009] in many respects, perhaps it is important to underline that we are not relying on any sort of mispricing argument in financial markets.[9]

We believe our paper contributes to existing literature in several ways. Under the assumptions of Q-Theory of Investment, q^{merton} is an economically and statistically significant factor to explain aggregate level of investment in the U.S. economy. Once the measurement errors in main variables of interest are alleviated it is possible to document a true underlying relationship between investment choices and their value to an economic agent. Our methodology is intended to provide an alternative framework to obtain market value of debt as a part of the market value of a firm's assets and its asset volatility. Although there may be many other models to price corporate debt, there is no consensus on how one structural model outperforms another in explaining bond prices. Most of the other pricing frameworks suffer a mispricing problem in this regard one way or another, and hence, it is still common to use Merton's model as a benchmark.[10]

Although the methodology in this paper can be extended and applied to many areas in the corresponding field, our approach can address and solve the measurement error problems in standard investment regressions. Many advantages of Merton's framework are also recognized

[8] R^2 in Table III on page 1034 of Philippon [2009] q^{bond} ($q^{classic}$) is 57% (10%). One standard deviation increase in q^{bond} is associated with 7.24% increase in investment rate at its mean. On the other hand, one standard deviation increase in $q^{classic}$ is associated with 2.95% increase in investment rate at its mean.

[9] Another important aspect of our framework is we do not relax any of the assumptions of Merton's original framework in our valuation, i.e. non-stochastic volatility structure.

[10] Geske [1977], Longstaff and Schwartz [1995], Collin-Dufresne and Goldstein [2001] and many other works relax the underlying assumption of Merton's framework and propose alternative ways to value corporate debt obligations. However, these models also suffer from over-predicting and under-predicting firm's default risk that belongs to different asset classes, i.e. investment vs. non-investment grade firms.

by practitioners in the industry, i.e. Moody's, Morningstar, and Standard & Poor's to calculate the risk profile of a firm in their respective credit rating methodologies. In short, our results complement the existing view, which argues that additional advances are necessary to provide better empirical models for testing the predictions of underlying theory. Therefore, it is crucial to realize the importance of accurate measurements in empirical proxies in order to identify the short-comings of underlying theoretical models.

The remainder of the paper is organized as follows. Section II explains the research design of this paper. Data samples and variable construction are presented in Section III. Empirical findings are provided in Section IV. Economic interpretation of our findings are presented in Section V. Robustness of the findings are tested in Section VI. Section VII concludes the paper. Finally, details of Merton's option pricing framework and supplementary information on sample characteristics are provided in the Appendix.

II. Research Design

We adopt a standard dynamic investment model by Erickson and Whited ([2000]; [2010]) in order to obtain our empirical framework. Risk-neutral managers choose investment to maximize firm value which is a function of invested capital. Hence, the value of a firm i at time t, $V_{i,t}$, is the following:

$$\begin{aligned} V_{i,t} =& E\Bigg[\sum_{j=0}^{\infty}\left(\prod_{s=1}^{j} b_{i,t+s}\right)[\pi(K_{i,t+j},\zeta_{i,t+j}) \\ & - \psi(I_{i,t+j},K_{i,t+j},v_{i,t+j},h_{i,t+j}) - I_{i,t+j}]\Bigg|\Omega_{i,t}\Bigg], \end{aligned} \tag{1}$$

where E is the expectation operator; $\Omega_{i,t}$ is the information set of the firm's manager at time t; $b_{i,t}$ is the firm's discount factor at time t; $K_{i,t}$ is the capital stock at the beginning of time-period; $I_{i,t}$ is the manager's investment decisions; $\pi(K_{i,t},\zeta_{i,t})$ is the firm's profit function with $\pi_K \geq 0$; and $\psi(I_{i,t},K_{i,t},v_{i,t},h_{i,t})$ is the investment adjustment cost function with $\psi_I \geq 0, \psi_K \leq$

$0, \psi_{II} \geq 0$, and $\psi_{KK} \geq 0$. Both $\zeta_{i,t}$ and $v_{i,t}$ are shocks to adjustment costs and profitability which is observable only to the manager. $h_{i,t}$ represents the other factors, i.e. labor costs that might also affect adjustment costs. Firm will maximize (1) with respect to the capital accumulation process,

$$K_{i,t+1} = (1 - \delta_i)K_{i,t} + I_{i,t}, \tag{2}$$

where δ_i denotes the firm-specific constant depreciation rate of capital. If we denote Lagrange multiplier with $q_{i,t}$, then the first order condition is the following:

$$1 + \psi_I(I_{i,t}, K_{i,t}, v_{i,t}, h_{i,t}) = q_{i,t}, \tag{3}$$

where

$$\begin{aligned} q_{i,t} =& E\Bigg[\sum_{j=0}^{\infty}\left(\prod_{s=1}^{j} b_{i,t+s}\right)(1-\delta_i)^{j-1}[\pi(K_{i,t+j}, \zeta_{i,t+j}) \\ & - \psi(I_{i,t+j}, K_{i,t+j}, v_{i,t+j}, h_{i,t+j}) - I_{i,t+j}]\Bigg|\Omega_{i,t}\Bigg]. \end{aligned} \tag{4}$$

The left hand side of equation (3) is marginal cost of additional unit of investment, whereas the right hand side of (4) is marginal benefit of the same unit of investment. By the price of unity assumption, $q_{i,t}$ is known as $q^{marginal}$ in standard investment equation, and it measures the marginal value and marginal cost of investment. However, a major challenge in such empirical framework is that $q^{marginal}$ is not readily observable, and it needs to be estimated.

In this regard it is standard in the literature to measure a firm's market value by adding market value of the firm's equity and book value of its liabilities, which we argue as a potential source of measurement error in variables in standard investment equations. Hence, we propose a new measure based on Merton's option pricing model.[11] By following Erickson and Whited [2000], we assume

$$\psi(I_{i,t}, K_{i,t}, v_{i,t}, h_{i,t}) = (a_1 + a_2 v_{i,t}) I_{i,t} + a_3 \frac{I_{i,t}^2}{K_{i,t}} + K_{i,t} f(v_{i,t}, h_{i,t}), \tag{5}$$

which is linearly homogenous in $I_{i,t}$ and $K_{i,t}$. We also assume, a_1, a_2, and a_3 are constant, and f is an integrable function. In order to obtain a concavity in value function, it is also necessary to assume $a_3 > 0$. Differentiating equation (5) with respect to $I_{i,t}$ will provide a standard investment regression model,

$$y_{i,t} = \alpha_0 + \beta q_{i,t} + u_{i,t}, \tag{6}$$

where $y_{i,t} = I_{i,t}/K_{i,t}$, $\alpha_0 = -(1 + a_1)/2a_3$, $\beta = 1/2a_3$, and $u_{i,t} = -a_2 v_{i,t}/2a_3$.[12] Equation (6) provides an empirical setting to test the implications of Q-Theory of Investment which suggests an investment rate should be related to q, if to anything.

III. Sample Selection and Variable Construction

The data sample consists of non-financial and non-utility U.S. firms within the intersection of Compustat Quarterly files and CRSP dataset from 1985 to 2007.[13,14] One of the main reasons why we focus on a data sample that starts from 1985 is due to the number of firms presented in Compustat annual and quarterly files, which are significantly different from each other in earlier years.[15] In addition, in later sections we identify the source of the explanatory power of

[11] We explain the construction of our measure more in detail in Section III and in Appendix I.

[12] We use a regression equation model (6) to analyze the association of q with investment at the aggregate level, which is obtained by aggregating all the corresponding components.

[13] If data that we need to construct our main variables of interest in Compustat Quarterly file is missing, we use the information in the Compustat Annual file to fill in corresponding missing variables accordingly.

[14] Our raw sample starts from 1980. However, due to the filtration of five years of non-missing information on constructed variables, we are initially losing 5 years of observations.

[15] In the annual Compustat file there were approximately 4,200 firms in late 1970s, whereas only 2,700 of these firms appear in the quarterly Compustat file.

q^{merton} in explaining investment level dynamics by using firm level information, i.e. the S&P long-term bond rating, which is only available after 1984.

A. Option Pricing Model Parameters

We derive the firm's asset value and its volatility by using Merton's option pricing framework, explained in further detail in Appendix I. Firm's idiosyncratic volatility is measured by the firm stock volatility over the calendar year, $\sigma_{E,t}$. We calculate the market value of the firm's equity by multiplying the firm's equity price with its outstanding shares, E. The risk free rate is instantaneous yield on a one year Treasury bond, r which is obtained from the Federal Reserve of Economic and Research Data (FRED). As in Bharath and Shumway [2008], the face value of debt is assumed to be equal to the sum of a firm's debt in its current liabilities and half of its longterm debt, F.

Market value of the firm's asset, $V_{A,t}$ and its volatility, $\sigma_{A,t}$, is obtained by solving equation (9) and equation (17)simultaneously and iteratively, where E, $\sigma_{E,t}$, r, and F are used as initial parameter estimates. Specifically, $\sigma_{E,t}$ is used as an initial input value for the estimation of $\sigma_{A,t}$ in equation (17). Using the Merton's formula for each trading day of the past 12 months, we compute firm asset value, $V_{A,t}$ by using $V_{E,t}$ as the market value of equity of that day. Afterwards we compute $\sigma_{A,t}$ of $V_{A,t}$, which is then used as inputs of $\sigma_{A,t}$ in equation (9) for the next iteration.

This procedure is repeated until the values of $\sigma_{A,t}$ from two consecutive iterations converge in values at a tolerance level of 0.001.[16] Once the value of $\sigma_{A,t}$ is obtained, we use it to obtain $V_{A,t}$ through equation (9).[17] This iteration process is repeated at the end of every month,

[16]For some firms, it takes only a few iterations for $\sigma_{A,t}$ to converge to a certain value, as is also the case in prior literature (Vassalou and Xing [2004]).

[17]Variation of this methodology is also used in the finance industry to estimate a firm's financial health and stability, i.e. firm's likelihood to default on its debt obligations. Moody's KMV methodology uses this approach to estimate credit worthiness of an economic entity (Vassalou and Xing [2004]; Bharath and Shumway [2008]). Specifically, Moody's KMV adopts Bayesian adjustments for the size of a country, an industry, and a firm to calculate its corresponding asset volatility. In addition, KMV also accounts for convertibles and preferred stocks in the firm's capital structure.

resulting in the estimation of monthly values of $\sigma_{A,t}$ and $V_{A,t}$. Time to maturity, T is always assumed to be 12 months in equation (9), along with the maturity of instantaneous risk-free rate, r.

B. Investment, Capital Stock & $q^{average}$ Measures

We obtain $q^{classic}$, q^{bond}, aggregate level of capital stock and investment measures by following Hall [2001] and Philippon [2009], respectively.[18] Hall's [2001] sample spanned the time period from 1946 to 1999. On the other hand, Philippon [2009] covered data from 1953 to 2007.[19] We use flow of funds data to construct $q^{classic}$, which is the ratio of the value of the firm adjusted for book value of its inventories to replacement cost of capital net of depreciation. Investment measure consists of non-residential fixed investment, scaled by current stock of capital at the beginning of the calendar year. In order to check the robustness of our findings, we also construct an aggregate level of investment by using the information from Compustat and CRSP merged databases.

We construct q^{merton} by using the market value of the firm from the iterative process that is explained in the previous section. Similar to alternative $q^{average}$ measures, we adjust this measure with the firm's inventory and then scale it by replacement cost of capital net of depreciation. In order to calculate aggregate measure, we take the sum of the firm's asset value adjusted for its inventories divided by the sum of replacement cost of its capital net of depreciation.

[18]We thank Robert E. Hall, and Thomas Philippon for providing their data. More details on construction of $q^{classic}$, q^{bond}, and investment variables used in this paper can be found in the corresponding papers.

[19]In order to extend the sample data to 2011 and check the robustness of our results in untabulated results, we closely follow the guideline provided by Hall [2001] to construct an aggregate level of investment and capital stock.

C. Control Variables

In order to check the explanatory power of q^{merton} against some other variables that appeared to be significant in prior literature, such as book leverage, idiosyncratic volatility, expected inflation, real discount factor, and relative price of corporate bonds, we closely follow Philippon [2009] and Hall ([2001]; [2004]). Moody's BAA rated corporate bond prices and treasury yields are obtained from FRED. Expected inflation comes from the Livingston survey. Idiosyncratic volatility is calculated by the methodology of Goyal and Santa-Clara [2003] as six months moving average volatility of daily stock returns. We calculate the aggregate level of book leverage, as the book value of corporate bonds divided by replacement cost of capital net of depreciation. Finally, we measure the aggregate level of cash flow by taking the sum of income before extraordinary items, depreciation and amortization and deferred taxes divided by the sum of capital stock net of depreciation.

D. Filtrations & Final Sample

Following Philippon [2009], we require that each firm has at least five years of non-missing information on constructed variables. We exclude LIFO firms from this sample.[20] We delete the observations if the firm has missing data on operating income, capital expenditure and asset value. We also require firms to have non-negative face value of debt and replacement cost of capital, which we measure by the firm's net plant property, plant, and equipment. Finally, we delete observations if a firm's net property plant and equipment is less than 20% of its total assets. The main reason for this filtration is to obtain a sample of firms with a significant portion of its assets consisting of tangible capital, since it is likely that an excluded firm's market value of assets reflect non-physical capital investments.[21] Table A.I in the Appendix II reports the average value of total asset components of firms that are included and excluded

[20] In order to have consistency in our inventory measure, we use first-in-first-out (FIFO) principal in our sample. This requirement caused us to loose 16% of the observations from the initial Compustat and CRSP merged file.

[21] We define firm's tangibility as the ratio of firm's capital stock net of depreciation to its total asset.

in our sample. The sample filtrations that we adopt provide a significant amount of deviation between market value of the firm's debt and its book value in our estimations. However, we relax these restrictions to check the robustness of our results and obtain qualitatively similar results.

IV. Results

We provide descriptive statistics of our sample from 1985 to 2007 in Panel A of Table I. Mean (standard deviation) value of I/K_H and I/K_P are 3.61% (0.39%), and 10.44% (0.91%), respectively. We believe the main reason for the discrepancy between the distribution of these two measures of investment is because of the assumption on the depreciation rate of capital stock.[22] Due to a similar reason, we observe the distributions of alternative q-measures are significantly different from each other. The sample mean of $q^{classic}\_H$ and $q^{classic}\_P$ are 1.58 and 2.63, respectively. In Panel A, we also provide the distribution of an alternative investment measure that is constructed from the sample of Compustat and CRSP merged data, I/K_C. Although the range of I/K_C is somewhat similar to I/K_H, we observe that it is relatively more volatile than it is counterparts.

When depreciation is assumed to be 30%, $q^{classic}$ has a relatively different distribution than its alternatives. However, q^{merton} is also relatively more (less) volatile than q^{bond} ($q^{classic}$). The mean of q^{merton} is 1.63, which is slightly higher than $q^{classic}$ and q^{bond}. Mean values of the real risk free rate, book leverage, idiosyncratic volatility, and inflation rate during 1985-2007 are also provided, which are 2.78%, 73.37%, 19.87% and 3.82%, respectively. Time series distributions of these values are also in close range to the reported values in prior literature (Hall [2001]; Hall [2003]). We also tabulate the summary statistics of these variables during

[22]Although Philippon [2009] did not specifically state the depreciation rate of physical capital that he used to construct his measures, we believe he used depreciation rate of 30%, whereas Hall [2001] assumed this rate as 10%.

the post-financial crisis in Panel B of Table I. We observe that inclusion of more recent years does not alter the distribution of our sample significantly at conventional levels.[23]

[Table I about here]

[Figure I about here]

In Figure I and Figure II, we provide time series distributions of alternative investment variables and $q^{average}$ proxies. We observe in Panel A of Figure I that investment level spikes up significantly after the first Gulf War. Alternative measures of investment are co-cyclical with each other throughout our time span. There is a significant reduction in investment following the technology bubble, as well as the recent financial crisis. In Panel B of Figure I, we observe a similar trend among I/K_H and I/K_C. However, I/K_C is relatively more volatile than its counterpart, which confirms our findings in Table I.

Regarding the alternative q-proxies, $q^{classic}$ under different depreciation rate assumptions and q^{merton} follow a similar time series pattern in Figure II. On the other hand, q^{bond} demonstrates a relatively more stable distribution over time than its counterparts as also reported in Philippon [2009]. From these figures we should also note that the value of an additional unit of capital increases after the first Gulf War and reaches its peak during the technology bubble.

[Figure II about here]

[Figure III about here]

In Figure III, we plot time series distribution of investment, I/K_H, against alternative q-proxies. Although we observe a degree of counter-cyclicality between investment and q^{merton} in earlier years, it is important to note that these variables are distributed relatively more in line with each other with respect to other proxy measures. This finding indicates that q^{merton} may perform better in explaining investment dynamics in a standard investment regression model,

[23] Since we do not observe Philippon's measures after 2007, we exclude the corresponding variables from Panel B of Table I.

which we also further analyze in detail in subsequent sections. As is reported in Philippon [2009], q^{bond} has a relatively more stationary distribution with respect to $q^{classic}$.

[Figure IV about here]

Among the variables that are documented to be closely associated with investment, we find that the spread between corporate and treasury bond yields and idiosyncratic volatility have the most pronounced similarity in variation in Figure IV. Book leverage shows an increasing time trend and varies less with investment over time. On the other hand, idiosyncratic volatility and bond spread are counter cyclical with investment since the 1980s.

[Table II about here]

We report the pairwise correlations between the interest variables in Table II. Among its alternatives q^{merton} has the highest correlation with I/K_H at 84.2%, where as q^{bond} has the lowest correlation with this variable at 64.6%, $q_H^{classic}$ is correlated with investment at 73.9% at the 1% statistically significance level. It is important to realize that we observe qualitatively similar pairwise correlations between alternative $q^{average}$ measures and I/K_P. We also find the highest correlation among alternative q-proxies is in between $q^{classic}\_H$ and q^{merton}, which is also significant at the 1% statistical significance level.

In addition to these findings, q^{bond} is positively correlated with the real risk free rate, and it is negatively correlated with real discount factor and bond spreads. On the other hand, q^{merton} is positively correlated with book leverage and idiosyncratic volatility, and it is negatively correlated with inflation rate. A similar correlation structure is detected between $q^{classic}$, book leverage, idiosyncratic volatility, and inflation rate. The correlation between $q^{classic}$ and bond spread is negative and significant at the 1% statistical level. I/K_H is negatively correlated with bond spreads and the inflation rate, whereas, I/K_P is positively correlated with the real risk free rate and idiosyncratic volatility. Overall, these results confirm our initial suspicion that q^{merton} might be an ideal candidate for explaining investment dynamics through a channel other than the associated measures. We turn to exploring these findings further in the remaining sections of this paper.

A. $q^{average}$ vs. I/K

We report our regression results of a simple investment model (6) along with the corresponding $adjusted - R^2$ of each model in Table III. The corresponding Newey-West standard errors are adjusted for autocorrelation up to four lags values. In order to be as conservative as possible in our analyses, we only denote the 5% and 1% statistical significance level with * and **, respectively. Intercept estimates are omitted in the reported results. In order to check the potential multicollinearity problem due to the high correlations among alternative q-proxies, we also report corresponding average variance inflation factor (VIF) test scores whenever they are needed.

One of the most important results in Panel A of Table III indicates that q^{merton} explains 71% of variation in I/K_H, which is approximately 30%(17%) higher than the level of variation captured by its alternatives such as q^{bond} and $q^{classic}\_H$, respectively. Reported results of Models I-III indicate that estimated slope coefficients are all statistically significant at the 1% statistical level. In fact, one standard deviation increase in $q^{classic}$, q^{bond}, and q^{merton} increases the investment rate by 8.03%, 7.03%, and 9.15% at its mean. In Models IV-VI we perform a horse race among alternative measures and include two proxies of $q^{average}$ simultaneously. In Model IV, both $q^{classic}$ and q^{bond} explain I/K_H statistically at the 1% significance level, which suggests these two proxies potentially capture different information about investment. On the other hand, Models V and VI show that q^{merton} performs best among its alternatives in explaining variation in I/K_H since it appears as the only variable that is statistically significant while not raising a concern about potential multicollinearity problems in model specification. Although there is a 3% improvement from Model III to Model V in regards to $adjusted - R^2$, we manage to obtain the highest level of goodness-of-fit score in a model when we include both q^{bond} and q^{merton} simultaneously.

[Table III about here]

We also check robustness of our results by using I/K under a different depreciation rate assumption and report the results in Panel B of Table III. The results are qualitatively similar to Panel A estimates. We observe that q^{merton} outperforms it is alternatives by obtaining the highest $adjusted - R^2$. However in Model V, q^{bond} also appears to be a significant factor to explain the aggregate investment level at the 1% significance level, even after we control for q^{merton}. We believe this result is mainly due to an underlying assumption of depreciation rate, and hence the corresponding capital stock accumulation process, since results in Model IV are also in line with this finding. Finally, average VIF test scores for each model indicates that multicollinearity is not an issue in our framework, which are all less than the conventional threshold value of ten.

B. q^{merton} vs. Other Factors

In Table IV, we analyze the performance of q^{merton} in explaining the variation in I/K against some of the other factors that are documented to be associated with investment in prior literature, i.e. bond spread, ratio of treasury and corporate bond yields, inflation rate, real risk free rate, book leverage, and idiosyncratic volatility. Our analysis adopts a similar framework as in equation (6) in a multivariate setting. Similarly to the previous set of analyses, we use alternative investment measures, I/K_H and I/K_P as a main variable interest to explain and report the corresponding findings in Panel A and Panel B, respectively. Further, in order to ensure that our results do not suffer from multicollinearity and autocorrelation, we report the adjusted Newey-West standard errors and corresponding VIF test scores.

[Table IV about here]

Results in Panel A indicate spread is negatively and book leverage is positively associated with I/K_H at the 5% significance level in Models I and II. However, once we control the effect of q^{merton} in Models III and IV, we find that q^{merton} is statistically significant at the 1% level in explaining the variation in investment, whereas spread and book leverage are both insignificant. In Model IV, idiosyncratic volatility and real discount factor are all negatively associated with investment at the 5% statistical level, which suggest that they are associated with investment through a channel other than the one controlled by q^{merton}. It is also important to note that $adjusted-R^2s$ of these regression models rises to 80% from 17% once q^{merton} is included. VIF test results at the component level as well as on average again indicate that neither model is subject to the multicollinearity problem.

These findings are also confirmed in Panel B when we use an alternative investment measure, I/K_P, as a dependent variable in our regressions. In Panel B q^{merton} appears to be significant at the 1% statistical level and positively associated with investment level. Further, other than spread and real risk free rate, all other control variables are negatively associated with the dependent variable. These findings are all statistically significant and contradict the prior literature that documents positive associations (Philippon [2009]). However, we believe these contradictions are due to the time span of our sample. Overall, these findings confirm the results in Table III and suggest that q^{merton} is an ideal candidate to explain aggregate level of investment since 1985. It is not only important that the estimated sign of slope coefficient is in line with the predictions of underlying theory, but it is also important to realize the amount of variation in investment that is explained by the variation in this new q-measure.

C. Explanatory Power of q^{merton}

In this section, we try explore in more detail the power of q^{merton} in explaining investment dynamics that is orthogonal to other factors that we control before shown in Tables III and IV. This set of analyses also ensures further the robustness of our findings in regards to potential collinear structure among the variables of interest. Instead of using the constructed measure of q^{merton}, we first regress q^{merton} on corresponding factors and report the results as in Models I and II. Afterwards, the residual component from these regressions are included in each model as in Tables III and IV, and reported as Models III and IV in Tables V and VI, respectively. In each panel of the corresponding table, we use alternative measures of investment. Consistent with our previous results, we control for potential autocorrelation in our estimations and report the associated Newey-West standard errors.

[Table V about here]

Results in Table V confirm the underlying correlation structure among alternative $q^{average}$ measures in Table II. Both q^{bond} and $q^{classical}$ measures are positively associated with our measure at the 1% significance level. Findings also confirm our previous results that q^{merton} explains a significant amount of variation in investment by a channel other than the one that is captured by these variables. However, it is also important to note from these results that q^{merton} as a whole manages to capture a substantial portion of association of both $q^{classic}$ and q^{bond} with investment.

Furthermore, we observe a similar effect of q^{merton} on investment in Table VI, even after we control for other standard variables. It is important to note from the results of Model II, idiosyncratic volatility and book leverage are positively associated with q^{merton} during our sample period. On the other hand, a relationship between credit yield spread and q^{merton} is negative. This is not surprising since the information in yield spreads is already reflected on asset values in our framework. Finally, in Models III and IV, we confirm the findings of Philippon [2009] regarding the association of components of q^{bond} and investment rate, except the real discount factor.

[Table VI about here]

V. Economic Interpretation

Our results so far confirm our initial intuition of using a structural approach to construct a $q^{average}$ measure powerful enough to explain the variation in investment at the aggregate level. In this set of analyses, we try to link the explanatory power of proposed measures to economically imbedded factors that might affect investment decisions of economic agents by focusing on firm level characteristics in our sample. We believe these analyses will also help us to identify the potential weaknesses of our methodology and identify potential avenues for future research to obtain an even better proxy.

[Table VII about here]

In Table VII, we report the median value of the sample characteristics of all firms that are sorted and assigned into three different groups depending on the deviation between corresponding market and book value of their debt.[24,25] We perform this group procedure in each quarter for every firm from 1985 to 2007. Hence, the small group represents the firms with the smallest amount of deviation between market and book value of their debt, and vice versa. We observe a monotonic trend across different groups in regards to their expected default probability, book leverage, size, q^{merton}, and their asset tangibility. Specifically, firms that are assigned to a small group have statistically lower leverage and lower asset tangibility but a higher q^{merton} with respect to their counterparts. It is also consistent that median expected default probability in this group is also the lowest. The economical value of our approach is mostly embedded in the sample of firms that are relatively risky and with more tangible capital, since we observe the largest discrepancy between the estimated market value of debt and its book value among these firms. In Panel B of Table VII we restrict our sample to those with S&P's credit ratings and also realize that risky firms have a larger difference between market value and book value of their debt.

[Table VIII about here]

In Table VIII, we perform a similar analysis as in Table VII by clustering firms into ten different groups by using their S&P's credit ratings. For instance, Group 0 includes firms that have no rating, whereas Group 9 includes the investment grade firms. We observe that the

[24] We define market value of debt as the difference between market value of asset that we obtain from Merton's option pricing model and market value of equity.

[25] In order to obtain this sample, we relax the restriction of at least 20% tangibility in assets in our data sampling.

largest deviation between market value of debt and its book value is mostly observed in the group of non-investment grade firms, such as the firms in Groups 3-6. Given the restriction of 20% asset tangibility that we use in our analyses, the findings on the performance of q^{merton} mostly come from the non-investment grade firms. This finding also confirms the conclusion of Jones, Mason and Rosenfeld [1984], and Eom, Helwege and Huang [2004], who state that the variation in predicted errors between realized and estimated yield spreads is lower for this type of firms. Overall, it is possible to filter out a certain amount of information in our sampling approach, however, the evidence is clear that pricing errors will be more in effect on the estimators without such restrictions.

VI. Robustness

In this section we check the robustness of our findings by first reconstructing an I/K measure by using the sample selection criteria that we use to measure q^{merton}. Second we extend our analysis to 2012 in order to incorporate the effect of the recent financial crisis. Finally, we analyze our findings by controlling the sensitivity of investment-to-cash flow in order to reconcile our framework with the corresponding literature.

[Table IX about here]

We present the regression results in Panel A of Table IX for a different sample of firms depending on alternative filtrations that we applied initially. For instance no filtration sample includes the firms that have asset tangibility less than 20%. In all four classifications, we observe that q^{merton} is positively associated with I/K_C at the 1% significance level. It is important to observe that the effect of our new q-proxy is much larger on investment for the sample of firms that satisfies both filtrations. Investment-to-cash flow sensitivity does not exist across different samples except the one that allows the inclusion of firms with a significant amount of intangible capital as is documented in Panel B of Table IX. However, it is also important to note that in our final sample, we obtain the most satisfactory test results with a highest level of $adjusted - R^2$.

[Table X about here]

Our findings in Table X confirm that our results are not mainly driven by the state of the economy before and after the crisis. However, we observe that cash flow proxy loses its explanatory power and it is insignificant whether or not the sample includes risky, small, or firms with intangible capital. Therefore, in future research, it will be interesting to analyze robustness of investment-to-cash flow sensitivity across time and across different samples.

VII. Conclusion

In this paper we adopt Merton's [1974] option pricing model to estimate a firm's asset value, which is then used to study the implementation of Q-Theory of Investment. During the time period from 1985 to 2007, our new $q^{average}$ measure, q^{merton}, manages to explain a 71% variation in the aggregate level of investment in the U.S. economy. Some other variables that are documented to be significantly associated with investment lose their explanatory power once q^{merton} is also controlled in a standard investment regression model. These results are robust during the recent financial crisis, as well as alternative investment measures in a sample of firms that are risky or have high levels of capital stock in physical assets.

Overall, our results support the view of measurement error problems in regressors of standard investment models. After we measure more accurately the market value of a firm's assets, explanatory power of q^{merton} increases significantly and carries more economical value in explaining investment choices of economic agents. Although we manage to capture much of the variation in investment with our measure at the aggregate level, it is still possible to modify the adopted framework in this paper to obtain a better proxy measure for marginal value of investment in a wider set of firms, i.e. firms with higher levels of intangible capital stock.

For instance, a potential avenue of research is to analyze how the Merton's pricing framework performs once other types of debt-like liabilities are capitalized, i.e. operating leases. Within a similar context, it remains for future research to explore in further detail whether or not the investment models at the firm level can be improved upon by addressing measurement errors in variables.

Appendix I

In this section we explain derivation of firm value by using Merton's [1974] option pricing model. At time t, suppose the firm has a book value of liability L_t with time to maturity T that pays zero coupons. The firm's value at the maturity is $V_{A,t+T}$. Hence, the probability of default will be the probability that $V_{A,t+T}$ is less than L_t.

Under Merton's framework, at any time t, the value of the firm $V_{A,t}$ follows a Geometric Brownian Motion:

$$dV_{A,t} = \mu_A V_{A,t} dt + \sigma_A V_{A,t} dW_t \tag{7}$$

where W_t is a standard Wiener process. $dW_t = \varepsilon_t \sqrt{dt}$, $\varepsilon_t \sim N(0,1)$.

Hence, the value of the firm at time $t+T$ is the following:

$$\ln V_{A,t+T} = \ln V_{A,t} + (\mu_A - \frac{1}{2}\sigma_A^2)T + \sigma_A \sqrt{T} \varepsilon_{t+T} \tag{8}$$

where $\varepsilon_{t+T} = \frac{W_{t+T} - W_t}{\sqrt{T}} \sim N(0,1)$.[26]

[26] If we ignore subscript t and A, (7) can be written as

$$dV = \mu V dt + \sigma V dW$$

let $G(V,t) = \ln V$, by the Taylor series expansion rule

$$dG = \frac{\partial G}{\partial V} dV + \frac{\partial G}{\partial t} dt + \frac{1}{2} \frac{\partial^2 G}{\partial V^2} dV^2 + (high\ order\ terms)$$

where $\frac{\partial G}{\partial V} = \frac{1}{V}$, $\frac{\partial G}{\partial t}$=0, and $\frac{\partial^2 G}{\partial V^2} = -\frac{1}{V^2}$.

$$dG = \frac{1}{V}(\mu V dt + \sigma V dW) + \frac{1}{2}(-\frac{1}{V^2})\sigma^2 V^2 dt = (\mu - \frac{1}{2}\sigma^2)dt + \sigma dW$$

We can also drive (8) by using Ito's lemma.

Therefore, probability of default can be written as

$$
\begin{aligned}
\mathrm{P}_{\text{default}} &= \mathrm{P}[\ln(V_{A,t+T}) \leq \ln(L_t)] \\
&= \mathrm{P}[\ln V_{A,t} + (\mu_A - \frac{1}{2}\sigma_A^2)T + \sigma_A^2\sqrt{T}\epsilon_{t+T} \leq \ln(L_t)] \\
&= \mathrm{P}(\epsilon_{t+T} \leq -\frac{\ln(\frac{V_{A,t}}{L_t}) + (\mu_A - \frac{1}{2}\sigma_A^2)T}{\sigma_A^2\sqrt{T}}) \\
&= \mathrm{N}(-\frac{\ln(\frac{V_{A,t}}{L_t}) + (\mu_A - \frac{1}{2}\sigma_A^2)T}{\sigma_A^2\sqrt{T}}) = \mathrm{N}(-DD_t)
\end{aligned}
$$

where DD_t is known as distance to default. Hence,

$$
\mathrm{DD}_t = \frac{\ln(\frac{V_{A,t}}{L_t}) + (\mu_A - \frac{1}{2}\sigma_A^2)T}{\sigma_A\sqrt{T}}.
$$

In order to calculate DD_t, one needs to know $V_{A,t}$, σ_A, and μ_A, which are not directly observable from the data. However, they can be estimated by using the option pricing model which treats a firm's equity as a call option written on the firm's assets with strike price, L_t, and time to maturity T. Firm's value to equity-holders at time t is

$$
\mathrm{V}_{E,t} = \max\left[\mathrm{V}_{A,t} - \mathrm{L}_t, 0\right]
$$

and, firm's value to debt-holders at time t is

$$
\mathrm{V}_{D,t} = \min\left[\mathrm{V}_{A,t}, \mathrm{L}_t\right] = \mathrm{L}_t - \max\left[\mathrm{L}_t - \mathrm{V}_{A,t}, 0\right]
$$

which are similar to European call option payoffs.

By using Black and Scholes's [1973] and Merton's [1974] option pricing frameworks, firm's equity value at time t is the following:

$$
\mathrm{V}_{E,t} = \mathrm{V}_{A,t}\mathrm{N}(\mathrm{d}_1) - \mathrm{L}_t e^{-rT}\mathrm{N}(\mathrm{d}_2) \tag{9}
$$

where $N(.)$ is cumulative density function of standard normal distribution, $\mathrm{d}_1 = \frac{\ln(\frac{V_{A,t}}{L_t})+(r+\frac{1}{2}\sigma_A^2)T}{\sigma_A\sqrt{T}}$, $\mathrm{d}_2 = \mathrm{d}_1 - \sigma_A\sqrt{T}$, and r is instantaneous risk-free rate.

Since $V_{E,t}$ is a function of $V_{A,t}$, and t, then

$$\begin{aligned} dV_{E,t} &= \frac{\partial V_{E,t}}{\partial V_{A,t}} dV_{A,t} + \frac{\partial V_{E,t}}{\partial t} dt + \frac{1}{2}\frac{\partial^2 V_{E,t}}{\partial V_{A,t}} dV_{A,t}^2 + (high\ order\ terms) \\ &= \mathrm{N}(d_1) dV_{A,t} + \frac{\partial V_{E,t}}{\partial t} dt + \frac{1}{2}\frac{\partial^2 V_{E,t}}{\partial V_{A,t}} {\sigma_A}^2 {V_{A,t}}^2 dt \qquad (10) \\ &= \mathrm{N}(d_1)\mu_A V_{A,t} dt + \sigma_A V_{A,t}\mathrm{N}(d_1) dW_t + \left[\frac{\partial V_{E,t}}{\partial t} + \frac{1}{2}\frac{\partial^2 V_{E,t}}{\partial V_{A,t}}\right] dt \\ &= \left[\mathrm{N}(d_1)\mu_A V_{A,t} + \frac{\partial V_{E,t}}{\partial t} + \frac{1}{2}\frac{\partial^2 V_{E,t}}{\partial V_{A,t}}\right] dt + \sigma_A V_{A,t}\mathrm{N}(d_1) dW_t. \qquad (11) \end{aligned}$$

where we use the Taylor series expansion rule to derive (10), such that

$$\frac{\partial V_{E,t}}{\partial V_{A,t}} = N(d_1) + V_{A,t}\frac{N(d_1)}{\partial V_{A,t}} - L_t e^{-rT}\frac{N(d_2)}{\partial V_{A,t}}$$

If we recall $N(d) = \int_{-\infty}^{d} f(x)dx$, where $f(x) = \frac{1}{\sqrt{2\pi}} e^{-\frac{x^2}{2}}$, and denote $N = N(d)$, and $d = d(V)$ for simplicity, then by using chain-rule

$$\frac{\partial N}{\partial V} = \frac{\partial N}{\partial d}\frac{\partial d}{\partial V} = \frac{\partial N}{\partial x}\bigg|_{x=d}\frac{\partial d}{\partial V} = f(x)\bigg|_{x=d}\frac{\partial d}{\partial V} = f(d)\frac{\partial d}{\partial V}.$$

which implies, $\frac{\partial N(d_1)}{\partial V_{A,t}} = f(d_1)\frac{\partial d_1}{\partial V_{A,t}} = f(d_1)\frac{1}{V_{A,t}\sigma_A\sqrt{T}}$, and similarly, $\frac{\partial N(d_2)}{\partial V_{A,t}} = f(d_2)\frac{1}{V_{A,t}\sigma_A\sqrt{T}}$. Therefore,

$$V_{A,t}\frac{\partial N(d_1)}{\partial V_{A,t}} = \frac{1}{\sigma_A\sqrt{2\pi T}} e^{-\frac{{d_1}^2}{2}} \qquad (12)$$

$$L_t e^{-rT}\frac{\partial N(d_2)}{\partial V_{A,t}} = \frac{L_t}{V_{A,t}\sigma_A\sqrt{2\pi T}} e^{-rT-\frac{{d_2}^2}{2}}. \qquad (13)$$

If we take logartihm of (12) and (13), we have

$$\ln\left[V_{A,t}\frac{\partial N(d_1)}{\partial V_{A,t}}\right] = -\ln(\sigma_A\sqrt{2\pi T}) - \frac{{d_1}^2}{2} \tag{14}$$

$$\ln\left[L_t e^{-rT}\frac{\partial N(d_2)}{\partial V_{A,t}}\right] = -\ln(\sigma_A\sqrt{2\pi T}) + \ln\left(\frac{L_t}{V_{A,t}}\right) - rT - \frac{{d_2}^2}{2} \tag{15}$$

Subtracting (15) from (14), we get

$$\begin{aligned}
\frac{d_2^2 - d_1^2}{2} + rT + \ln\left(\frac{V_{A,t}}{L_t}\right) &= \frac{(d_2 - d_1)(d_2 + d_1)}{2} + rT + \ln\left(\frac{V_{A,t}}{L_t}\right) \\
&= \frac{2\ln\left(\frac{V_{A,t}}{L_t}\right) + 2rT}{2\sigma_A\sqrt{T}}(-\sigma_A\sqrt{T}) + rT + \ln\left(\frac{V_{A,t}}{L_t}\right) \\
&= -\ln\left(\frac{V_{A,t}}{L_t}\right) - rT + rT + \ln\left(\frac{V_{A,t}}{L_t}\right) = 0.
\end{aligned}$$

which implies $\frac{\partial V_{E,t}}{\partial V_{A,t}} = N(d_1)$.

Now, we can write the dynamics of $V_{E,t}$ as

$$dV_{E,t} = \mu_E V_{E,t} dt + \sigma_E V_{E,t} dW_t \tag{16}$$

By using equations (16) and (11), we can obtain

$$\sigma_E V_{E,t} = \sigma_A V_{A,t} N(d_1).$$

and it implies

$$\sigma_E = \left(\frac{V_{A,t}}{V_{E,t}}\right) N(d_1)\sigma_A. \tag{17}$$

Therefore, $P_{default}$, $V_{A,t}$, and σ_A can be obtained by solving (9) and (17) iteratively.

Appendix II

Table A.1. Mean value of assets

	Firms with Tangibility>=0.2		Firms with Tangibility<0.2	
	Level (Millions)	Percentage	Level (Millions)	Percentage
Assets - Total	1266.43	100.0%	850.15	100.0%
Current Assets - Total	352.51	27.8%	298.87	35.2%
Cash and Short-Term Investments	83.74	6.6%	119.62	14.1%
Current Assets - Other - Total	39.91	3.2%	35.12	4.1%
Inventories - Total	100.53	7.9%	73.87	8.7%
Receivables - Total	133.86	10.6%	120.31	14.2%
Property, Plant and Equipment (Net) - Total	*594.25*	*46.9%*	*85.09*	*10.0%*
Investment & Advances - Equity	0.00	0.0%	0.00	0.0%
Investment & Advances - Other	0.00	0.0%	0.00	0.0%
Intangible Assets - Total	96.74	7.6%	177.75	20.9%
Assets - Other - Total	313.85	24.8%	416.00	48.9%

This table provides the mean value of firms' assets and asset components from Compustat Quarterly files that are included and excluded in our sample from 1985 to 2007. Missing values are treated as zero.

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Table I. Descriptive Statistics: Quarterly Aggregate Data

Panel A: 1985Q1-2007Q2

	N.Obs	Mean	Std.Dev.	Min	Max
I/K_H	90	0.0361	0.0039	0.0306	0.0441
I/K_P	90	0.1044	0.0091	0.0887	0.1254
I/K_C	90	0.0413	0.0106	0.0165	0.0669
$q^{classic}$_H	90	1.5753	0.5811	0.6624	3.2729
$q^{classic}$_P	90	2.6306	0.8674	1.2134	4.9890
q^{bond}	90	1.5357	0.0951	1.2971	1.7198
q^{merton}	90	1.6328	0.4788	0.9861	3.0993
Cash Flow	90	0.0340	0.0190	-0.0134	0.0675
$(0.1+r^{10})/(0.1+y^{Baa})$	90	0.8877	0.0302	0.7862	0.9319
Spread: $[y^{Baa}-r^{10}]$	90	0.0208	0.0051	0.0130	0.0379
Real risk free rate	90	0.0278	0.0095	0.0113	0.0568
Book leverage	90	0.7337	0.1441	0.4119	0.9606
Real discount factor	90	0.8356	0.0405	0.7438	0.9189
Inflation	90	0.0382	0.0119	0.0196	0.0648
Idiosyncratic volatility	90	0.1987	0.0414	0.1204	0.2897

Panel B: 1985Q1-2011Q1

	N.Obs	Mean	Std.Dev.	Min	Max
I/K_H	105	0.0354	0.0044	0.0258	0.0441
I/K_C	105	0.0398	0.0112	0.0124	0.0669
$q^{classic}$_H	105	1.5602	0.5527	0.6624	3.2729
q^{merton}	105	1.5734	0.4763	0.8284	3.0993
Cash Flow	105	0.0314	0.0219	-0.0830	0.0675
$(0.1+r^{10})/(0.1+y^{Baa})$	105	0.8769	0.0451	0.6902	0.9319
Spread: $[y^{Baa}-r^{10}]$	105	0.0224	0.0077	0.0130	0.0562
Real risk free rate	105	0.0254	0.0111	-0.0077	0.0568
Book leverage	105	0.7729	0.1670	0.4119	1.1568
Real discount factor	105	0.8483	0.0535	0.7438	1.0614
Inflation	105	0.0365	0.0119	0.0196	0.0648
Idiosyncratic volatility	105	0.1988	0.0485	0.1134	0.3718

Three measures of investment over replacement cost of capital net of depreciation, I/K_H, I/K_P and I/K_C are constructed as in Hall [2001], Philippon [2009], and from the quarterly Compustat-CRSP sample, respectively. $q^{classic}$_H is constructed as in Hall [2001]. $q^{classic}$_P and q^{bond} are from Philippon [2009]. q^{merton} is the aggregate market value of firms net of inventories, scaled by aggregate replacement cost of capital net of depreciation. Replacement cost of capital net of depreciation is the book value of firm's net total property, plant and equipment. Cash flow is measured by the sum of firm's income before extraordinary items, depreciation and amortization, and deferred taxes, scaled by replacement cost of capital net of depreciation. Relative price of treasury and corporate bonds, credit spread, real risk free rate, book leverage, and real discount factor are constructed as in Philippon [2009]. Moody's BAA rated corporate bond prices and treasury yields are from FRED. Expected inflation is from the Livingston survey. Idiosyncratic volatility is calculated as in Goyal and Santa-Clara [2003].

Table II. Pearson Correlations: Quarterly Aggregate Data, 1985Q1-2007Q2

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
(1)	1														
(2)	0.916**	1													
(3)	0.740**	0.705**	1												
(4)	0.739**	0.621**	0.407**	1											
(5)	0.704**	0.616**	0.368**	0.984**	1										
(6)	0.646**	0.631**	0.732**	0.330**	0.291**	1									
(7)	0.842**	0.768**	0.653**	0.867**	0.857**	0.618**	1								
(8)	0.699**	0.613**	0.487**	0.492**	0.471**	0.459**	0.591**	1							
(9)	0.223*	0.175	0.458**	-0.218*	-0.305**	0.734**	0.0381	0.166	1						
(10)	-0.330**	-0.187	-0.476**	0.00590	0.102	-0.743**	-0.155	-0.263*	-0.942**	1					
(11)	0.0816	0.249*	0.220*	-0.372**	-0.388**	0.384**	-0.136	0.0222	0.604**	-0.370**	1				
(12)	0.103	-0.174	-0.121	0.536**	0.529**	-0.176	0.208*	0.149	-0.323**	0.0117	-0.708**	1			
(13)	-0.201	-0.333**	-0.270*	0.183	0.199	-0.436**	0.000752	-0.103	-0.574**	0.393**	-0.962**	0.559**	1		
(14)	-0.315**	-0.126	0.0452	-0.709**	-0.722**	0.200	-0.372**	-0.265*	0.500**	-0.219*	0.583**	-0.817**	-0.364**	1	
(15)	0.177	0.219*	0.0772	0.335**	0.398**	0.108	0.478**	0.0276	-0.338**	0.401**	-0.0478	-0.0776	0.0259	-0.0212	1

(1) is I/K_H. (2) is I/K_P. (3) is I/K_C. (4) is $q^{classic}$_H. (5) is $q^{classic}$_P. (6) is q^{bond}. (7) is q^{merton}. (8) is cash flow. (9) is $(0.1+r^{10})$ $/(0.1+ y^{Baa})$. (10) is credit spread: $[y^{Baa}$-$r^{10}]$. (11) is real risk free rate. (12) is book leverage. (13) is real discount factor. (14) is inflation. (15) is idiosyncratic volatility.
Three measures of investment over replacement cost of capital net of depreciation, I/K_H, I/K_P and I/K_C are constructed as in Hall [2001], Philippon [2009], and from the quarterly Compustat-CRSP sample, respectively. $q^{classic}$_H is constructed as in Hall [2001]. $q^{classic}$_P and q^{bond} are from Philippon [2009]. q^{merton} is the aggregate market value of firms net of inventories, scaled by aggregate replacement cost of capital net of depreciation. Replacement cost of capital net of depreciation is the book value of firm's net total property, plant and equipment. Cash flow is measured by the sum of firm's income before extraordinary items, depreciation and amortization, and deferred taxes, scaled by replacement cost of capital net of depreciation. Relative price of treasury and corporate bonds, credit spread, real risk free rate, book leverage, and real discount factor are constructed as in Philippon [2009]. Moody's BAA rated corporate bond prices and treasury yields are from FRED. Expected inflation is from the Livingston survey. Idiosyncratic volatility is calculated as in Goyal and Santa-Clara [2003]. ** and * indicate significance at the 1% and 5% levels, respectively.

Table III. Investment Regressions: Quarterly Aggregate Data, 1985Q1-2007Q2

Panel A. Dependent variable in levels: I(t)/K(t-1)_H

	Model I	Model II	Model III	Model IV	Model V	Model VI
$q^{classic}$_H(t-1)	0.00499**			0.00399**		0.000253
s.e.	(0.000774)			(0.000832)		(0.00129)
q^{bond}(t-1)		0.0267**		0.0186**	0.00839	
s.e.		(0.00515)		(0.00339)	(0.00441)	
q^{merton}(t-1)			0.00690**		0.00587**	0.00664**
s.e.			(0.000705)		(0.00103)	(0.00122)
N.Obs.	90	90	90	90	90	90
Adj.R-square	0.541	0.411	0.706	0.722	0.728	0.703
Average VIF	1.00	1.00	1.00	1.12	1.62	4.02

Panel B. Dependent variable in levels: I(t)/K(t-1)_P

	Model I	Model II	Model III	Model IV	Model V	Model VI
$q^{classic}$_P(t-1)	0.00644**			0.00494**		-0.00169
s.e.	(0.00192)			(0.00174)		(0.00244)
q^{bond}(t-1)		0.0601**		0.0470**	0.0241**	
s.e.		(0.0117)		(0.00688)	(0.00883)	
q^{merton}(t-1)			0.0145**		0.0116**	0.0172**
s.e.			(0.00229)		(0.00303)	(0.00288)
N.Obs.	90	90	90	90	90	90
Adj.R-square	0.372	0.391	0.586	0.593	0.621	0.588
Average VIF	1.00	1.00	1.00	1.09	1.62	3.78

Two measures of investment over replacement cost of capital net of depreciation, I/K_H and I/K_P are constructed as in Hall [2001] and Philippon [2009], respectively. $q^{classic}$_H is constructed as in Hall [2001]. $q^{classic}$_P and q^{bond} are from Philippon [2009]. q^{merton} is the aggregate market value of firms net of inventories, scaled by aggregate replacement cost of capital net of depreciation. Replacement cost of capital net of depreciation is the book value of firm's net total property, plant and equipment. Newey-West standard errors with autocorrelation up to 4 lags are reported in parentheses. ** and * indicate significance at the 1% and 5% levels, respectively. Constant terms are omitted.

Table IV. Investment Regressions: Quarterly Aggregate Data, 1985Q1-2007Q2

	Panel A			
	Dependent variable in levels: I(t)/K(t-1)_H			
	Model I	Model II	Model III	Model IV
Spread: $[y^{Baa} - r^{10}]$*(t-1)*	-0.359*		0.0410	
s.e.	(0.145)		(0.0790)	
Real risk free rate (t-1)	0.0206		0.107*	
s.e.	(0.0947)		(0.0444)	
Idiosyncratic volatility (t-1)	0.0360	0.0301	-0.0302*	-0.0298*
s.e.	(0.0216)	(0.0214)	(0.0124)	(0.0116)
Book leverage (t-1)	0.00470	0.00969*	0.00127	-0.000875
s.e.	(0.00503)	(0.00369)	(0.00226)	(0.00288)
$[0.1+r^{10}]/[0.1+y^{Baa}]$ *(t-1)*		0.0410		-0.00628
s.e.		(0.0275)		(0.0134)
Real discount factor (t-1)		-0.0220		-0.0197*
s.e.		(0.0169)		(0.00769)
q^{merton} *(t-1)*			0.00843**	0.00820**
s.e.			(0.000787)	(0.000703)
N.Obs.	90	90	90	90
Adj.R-square	0.207	0.172	0.807	0.803
	VIF			
Spread: $[y^{Baa} - r^{10}]$*(t-1)*	1.59		2.06	
Real risk free rate (t-1)	2.73		2.81	
Idiosyncratic volatility (t-1)	1.21	1.20	2.06	1.86
Book leverage (t-1)	2.35	1.48	2.37	1.73
$[0.1+r^{10}]/[0.1+y^{Baa}]$ *(t-1)*		1.77		1.99
Real discount factor (t-1)		1.98		1.98
q^{merton} *(t-1)*			1.84	1.66
Average VIF	1.97	1.61	2.23	1.84

Two measures of investment over replacement cost of capital net of depreciation, I/K_H and I/K_P are constructed as in Hall [2001] and Philippon [2009], respectively. q^{merton} is the aggregate market value of firms net of inventories, scaled by aggregate replacement cost of capital net of depreciation. Replacement cost of capital net of depreciation is the book value of firm's net total property, plant and equipment. Relative price of treasury and corporate bonds, credit spread, real risk free rate, book leverage, and real discount factor are constructed as in Philippon [2009]. Moody's BAA rated corporate bond prices and treasury yields are from FRED. Expected inflation is from the Livingston survey. Idiosyncratic volatility is calculated as in Goyal and Santa-Clara [2003]. Newey-West standard errors with autocorrelation up to 4 lags are reported in parentheses. ** and * indicate significance at the 1% and 5% levels, respectively. Constant terms are omitted.

TABLE IV (Continued). Investment Regressions: Quarterly Aggregate Data, 1985Q1-2007Q2

Panel B

	Dependent variable in levels: I(t)/K(t-1)_P			
	Model I	Model II	Model III	Model IV
Spread: [$y^{Baa} - r^{10}$](t-1)	-0.488		0.500**	
s.e.	(0.344)		(0.189)	
Real risk free rate (t-1)	0.116		0.329**	
s.e.	(0.237)		(0.0788)	
Idiosyncratic volatility (t-1)	0.0722	0.0584	-0.0911**	-0.0849**
s.e.	(0.0562)	(0.0539)	(0.0338)	(0.0316)
Book leverage (t-1)	-0.00369	0.00338	-0.0122*	-0.0219**
s.e.	(0.0121)	(0.00790)	(0.00570)	(0.00650)
[0.1+r^{10}]/[0.1+y^{Baa}] (t-1)		0.0314		-0.0817*
s.e.		(0.0641)		(0.0343)
Real discount factor (t-1)		-0.0692		-0.0638**
s.e.		(0.0425)		(0.0142)
q^{merton} (t-1)			0.0208**	0.0196**
s.e.			(0.00203)	(0.00182)
N.Obs.	90	90	90	90
Adj.R-square	0.125	0.131	0.809	0.808

	VIF			
Spread: [$y^{Baa} - r^{10}$](t-1)	1.59		2.06	
Real risk free rate (t-1)	2.73		2.81	
Idiosyncratic volatility (t-1)	1.21	1.2	2.06	1.86
Book leverage (t-1)	2.35	1.48	2.37	1.73
[0.1+r^{10}]/[0.1+y^{Baa}] (t-1)		1.77		1.99
Real discount factor (t-1)		1.98		1.98
q^{merton} (t-1)			1.84	1.66
Average VIF	1.97	1.61	2.23	1.84

Two measures of investment over replacement cost of capital net of depreciation, I/K_H and I/K_P are constructed as in Hall [2001] and Philippon [2009], respectively. q^{merton} is the aggregate market value of firms net of inventories, scaled by aggregate replacement cost of capital net of depreciation. Replacement cost of capital net of depreciation is the book value of firm's net total property, plant and equipment. Relative price of treasury and corporate bonds, credit spread, real risk free rate, book leverage, and real discount factor are constructed as in Philippon [2009]. Moody's BAA rated corporate bond prices and treasury yields are from FRED. Expected inflation is from the Livingston survey. Idiosyncratic volatility is calculated as in Goyal and Santa-Clara [2003]. Newey-West standard errors with autocorrelation up to 4 lags are reported in parentheses. ** and * indicate significance at the 1% and 5% levels, respectively. Constant terms are omitted.

Table V. Residual Investment Regressions: Quarterly Aggregate Data, 1985Q1-2007Q2

Panel A. Dependent variable in levels:

	q^{merton}		I(t)/K(t-1)_H	
	Model I	Model II	Model III	Model IV
$q^{classic}$_H	0.714**		0.00499**	
s.e.	(0.0438)		(0.000717)	
q^{bond}		3.111**		0.0267**
s.e.		(0.422)		(0.00251)
Model I Residual			0.00664**	
s.e.			(0.00122)	
Model II Residual				0.00587**
s.e.				(0.00103)
N.Obs.	90	90	90	90
Adj.R-square	0.749	0.375	0.703	0.728

Panel B. Dependent variable in levels:

	q^{merton}		I(t)/K(t-1)_P	
	Model I	Model II	Model III	Model IV
$q^{classic}$_P	0.473**		0.00644**	
s.e.	(0.0303)		(0.00158)	
q^{bond}		3.111**		0.0601**
s.e.		(0.422)		(0.00597)
Model I Residual			0.0172**	
s.e.			(0.00288)	
Model II Residual				0.0116**
s.e.				(0.00303)
N.Obs.	90	90	90	90
Adj.R-square	0.732	0.375	0.588	0.621

Two measures of investment over replacement cost of capital net of depreciation, I/K_H and I/K_P are constructed as in Hall [2001] and Philippon [2009], respectively. $q^{classic}$_H is constructed as in Hall [2001]. $q^{classic}$_P and q^{bond} are from Philippon [2009]. q^{merton} is the aggregate market value of firms net of inventories, scaled by aggregate replacement cost of capital net of depreciation. Replacement cost of capital net of depreciation is the book value of firm's net total property, plant and equipment. Models I and II are the regressions of q^{merton} on alternative q measures. Models III and IV are the regressions of investment on alternative q measures and the residuals of Model I and II, respectively. Newey-West standard errors with autocorrelation up to 4 lags are reported in parentheses. ** and * indicate significance at the 1% and 5% levels, respectively. Constant terms are omitted.

Table VI. Residual Investment Regressions: Quarterly Aggregate Data, 1985Q1-2007Q2

	Panel A. Dependent variable in levels: q^{merton}		I(t)/K(t-1)_H	
	Model I	Model II	Model III	Model IV
Spread: [yBaa-r10](t-1)	-47.49**		-0.359**	
s.e.	(9.498)		(0.0571)	
Real risk free rate (t-1)	-10.26		0.0206	
s.e.	(6.663)		(0.0440)	
Idiosyncratic volatility (t-1)	7.857**	7.297**	0.0360**	0.0301**
s.e.	(1.016)	(1.069)	(0.00851)	(0.00871)
Book leverage (t-1)	0.407	1.288**	0.00470*	0.00969**
s.e.	(0.407)	(0.340)	(0.00221)	(0.00271)
[0.1+r10]/[0.1+yBaa] (t-1)		5.759**		0.0410**
s.e.		(1.779)		(0.0111)
Real discount factor (t-1)		-0.277		-0.0220**
s.e.		(1.402)		(0.00770)
Model I Residual			0.00843**	
s.e.			(0.000787)	
Model II Residual				0.00820**
s.e.				(0.000703)
N.Obs.	90	90	90	90
Adj.R-square	0.431	0.368	0.807	0.803

	Panel B. Dependent variable in levels: q^{merton}		I(t)/K(t-1)_P	
	Model I	Model II	Model III	Model IV
Spread: [yBaa-r10](t-1)	-47.49**		-0.488**	
s.e.	(9.498)		(0.126)	
Real risk free rate (t-1)	-10.26		0.116	
s.e.	(6.663)		(0.0826)	
Idiosyncratic volatility (t-1)	7.857**	7.297**	0.0722**	0.0584*
s.e.	(1.016)	(1.069)	(0.0228)	(0.0230)
Book leverage (t-1)	0.407	1.288**	-0.00369	0.00338
s.e.	(0.407)	(0.340)	(0.00547)	(0.00565)
[0.1+r10]/[0.1+yBaa] (t-1)		5.759**		0.0314
s.e.		(1.779)		(0.0273)
Real discount factor (t-1)		-0.277		-0.0692**
s.e.		(1.402)		(0.0141)
Model I Residual			0.0208**	
s.e.			(0.00203)	
Model II Residual				0.0196**
s.e.				(0.00182)
N.Obs.	90	90	90	90
Adj.R-square	0.431	0.368	0.809	0.808

Two measures of investment over replacement cost of capital net of depreciation, I/K_H and I/K_P are constructed as in Hall [2001] and Philippon [2009], respectively. q^{merton} is the aggregate market value of firms net of inventories, scaled by aggregate replacement cost of capital net of depreciation. Replacement cost of capital net of depreciation is the book value of firm's net total property, plant and equipment. Relative price of treasury and corporate bonds, credit spread, real risk free rate, book leverage, and real discount factor are constructed as in Philippon [2009]. Moody's BAA rated corporate bond prices and treasury yields are from FRED. Expected inflation is from the Livingston survey. Idiosyncratic volatility is calculated as in Goyal and Santa-Clara [2003]. Models I and II are the regressions of q^{merton} on other factors. Models III and IV are the regressions of investment on other factors and the residuals from Model I and II, respectively. Newey-West standard errors with autocorrelation up to 4 lags are reported in parentheses. ** and * indicate significance at the 1% and 5% levels, respectively. Constant terms are omitted.

Table VII. Firm level characteristics

Panel A. Sample of all firms (1985Q1-2007Q2)

	Sort by (BVD-MVD)/MVD		
	Small	Middle	Big
(BVD-MVD)/MVD	0.0122	0.6912	1.1824
Book Leverage	0.0271	0.2376	0.3058
Asset Tangibility	0.1330	0.2465	0.2591
Log(Total Asset)	3.6655	4.5259	5.0575
q^{merton}	11.7612	3.5347	2.9621
Probability of default	0.0000	0.0011	0.0019

Panel B. Sample of all firms with credit ratings (1985Q4-2007Q2)

	Sort by (BVD-MVD)/MVD		
	Small	Middle	Big
(BVD-MVD)/MVD	0.6157	1.0095	1.2332
Book Leverage	0.2882	0.3666	0.4056
Asset Tangibility	0.2670	0.3283	0.3090
Log(Total Asset)	7.4140	7.0118	6.8617
q^{merton}	3.5129	2.2206	2.2112
Probability of default	0.0003	0.0003	0.0059

Firms are sorted into three groups by the difference between book value (BVD) and market value (MVD) of debt scaled by market value of debt. Book value of debt is the sum of short term debt and long term debt. Market value of debt is the difference between market value of asset and market value of equity. Market value of asset is from Merton's [1974] option pricing model. Market value of equity is the firm's equity price multiplied by its outstanding shares. Book leverage is measured by book value of debt divided by total asset. Asset tangibility is net total property, plant and equipment divided by total asset. q^{merton} is market value of asset divided by replacement cost of capital net of depreciation. Replacement cost of capital is the book value of firm's net total property, plant and equipment. All variables are time series average of cross sectional median in each quarter.

Table VIII. Firm level characteristics: 1985Q1-2007Q2

	Sample of all firms									
	0	1	2	3	4	5	6	7	8	9
(BVD-MVD)/MVD	0.5347	0.4522	0.6809	1.1018	1.0584	1.0364	0.9606	0.8611	0.7189	0.7514
Book Leverage	0.0570	0.0843	0.1386	0.6222	0.4589	0.3432	0.2468	0.2230	0.2072	0.1027
Asset Tangibility	0.1139	0.1435	0.3403	0.3532	0.2750	0.2411	0.2317	0.2449	0.2880	0.1975
Log(Total Asset)	4.6290	4.6866	5.8553	6.2521	6.5319	7.2272	8.1629	9.0028	9.9586	10.4245
q^{merton}	15.4134	9.9811	0.7337	1.7747	2.7213	3.1149	4.8673	6.3045	8.8738	14.1547
Probability of default	0.0002	0.0002	0.2468	0.2801	0.0205	0.0047	0.0000	0.0000	0.0000	0.0000
Percentage of Total obs	19.40	64.43	0.15	0.50	4.16	4.86	3.63	2.07	0.57	0.26

Firms are sorted into 10 groups by the S&Ps Domestic Long Term Issuer Credit Ratings: AAA firms are in group 9; AA+, AA, AA- firms are in group 8; A+, A, A- firms are in group 7; BBB+, BBB, BBB- firms are in group 6; BB+, BB, BB- firms are in group 5; B+, B, B- firms are in group 4; CCC+, CCC, CCC-, CC firms are in group 3; C, D, N.M., SD, Suspended firms are in group 2; firms appeared in the rating file but with missing rating is in group 1; firms do not appear in the rating file is in group 0. Book value of debt is the sum of short term debt and long term debt. Market value of debt is the difference between market value of asset and market value of equity. Market value of asset is from Merton's [1974] option pricing model. Market value of equity is the firm's equity price multiplied by its outstanding shares. Book leverage is measured by book value of debt divided by total asset. Asset tangibility is net total property, plant and equipment divided by total asset. q^{merton} is market value of asset divided by replacement cost of capital net of depreciation. Replacement cost of capital is the book value of firm's net total property, plant and equipment. All variables are time series average of cross sectional median in each quarter.

Table IX. Investment regression, 1985Q1-2007Q2

	Dependent variable in levels: I/K_C			
	Panel A			
	No filtration	Tangibility>=0.2	Iteration>=2	Both filtrations
q^{merton}	0.00242**	0.00554**	0.00938**	0.0144**
s.e	(0.000665)	(0.00109)	(0.00177)	(0.00253)
N. Obs.	90	90	90	90
Adj. R-square	0.195	0.276	0.295	0.420
	Panel B			
	No filtration	Tangibility>=0.2	Iteration>=2	Both filtrations
q^{merton}	0.00265**	0.00659**	0.00681**	0.0124**
s.e	(0.000927)	(0.00162)	(0.00173)	(0.00269)
Cash Flow	-0.0209	-0.0634	0.129**	0.0864
s.e	(0.0617)	(0.0701)	(0.0438)	(0.0543)
N. Obs.	90	90	90	90
Adj. R-square	0.188	0.280	0.346	0.430

Dependent variable I/K_C and the corresponding independent variables are constructed by applying different filtrations on the quarterly Compustat-CRSP sample. No filtration is the sample of entire Compustat-CSRP sample. Tangibility >= 0.2 is the sample of firms with asset tangibility more than or equal to 20%. Iteration >= 2 is the sample of firms with at least 2 iterations in Merton's [1974] option pricing framework. Both filtrations is the sample of firms that satisfies both tangibility and iteration filtrations. Asset tangibility is net total property, plant and equipment divided by total asset. q^{merton} is the aggregate market value of firms net of inventories, scaled by aggregate replacement cost of capital net of depreciation. Replacement cost of capital net of depreciation is the book value of firm's net total property, plant and equipment. Cash flow is measured by the sum of firm's income before extraordinary items, depreciation and amortization, and deferred taxes, scaled by replacement cost of capital net of depreciation. Newey-West standard errors with autocorrelation up to 4 lags are reported in parentheses. ** and * indicate significance at the 1% and 5% levels, respectively. Constant terms are omitted.

Table X. Investment regression, 1985Q1-2012Q4

	Dependent variable in levels: I/K_C			
	Panel A			
	No filtration	Tangibility>=0.2	Iteration>=2	Both filtrations
q^{merton}	0.00243**	0.00604**	0.0103**	0.0151**
s.e	(0.000660)	(0.00114)	(0.00177)	(0.00227)
N. Obs.	112	112	112	112
Adj. R-square	0.177	0.301	0.326	0.423
	Panel B			
	No filtration	Tangibility>=0.2	Iteration>=2	Both filtrations
q^{merton}	0.00313**	0.00710**	0.00947**	0.0143**
s.e	(0.000854)	(0.00140)	(0.00213)	(0.00259)
Cash Flow	-0.0585	-0.0693	0.0427	0.0304
s.e	(0.0412)	(0.0494)	(0.0514)	(0.0501)
N. Obs.	112	112	112	112
Adj. R-square	0.194	0.312	0.328	0.420

Dependent variable I/K_C and the corresponding independent variables are constructed by applying different filtrations on the quarterly Compustat-CRSP sample. No filtration is the sample of entire Compustat-CSRP sample. Tangibility >= 0.2 is the sample of firms with asset tangibility more than or equal to 20%. Iteration >= 2 is the sample of firms with at least 2 iterations in Merton's [1974] option pricing framework. Both filtrations is the sample of firms that satisfies both tangibility and iteration filtrations. Asset tangibility is net total property, plant and equipment divided by total asset. q^{merton} is the aggregate market value of firms net of inventories, scaled by aggregate replacement cost of capital net of depreciation. Replacement cost of capital net of depreciation is the book value of firm's net total property, plant and equipment. Cash flow is measured by the sum of firm's income before extraordinary items, depreciation and amortization, and deferred taxes, scaled by replacement cost of capital net of depreciation. Newey-West standard errors with autocorrelation up to 4 lags are reported in parentheses. ** and * indicate significance at the 1% and 5% levels, respectively. Constant terms are omitted.

Figure 1. Alternative investment measures

Three measures of investment over replacement cost of capital net of depreciation, I/K_H, I/K_P and I/K_C are constructed as in Hall [2001], Philippon [2009], and from the quarterly Compustat-CRSP sample, respectively. Replacement cost of capital net of depreciation is the book value of firm's net total property, plant and equipment. (a) I/K_H vs. I/K_P; (b) I/K_H vs. I/K_C.

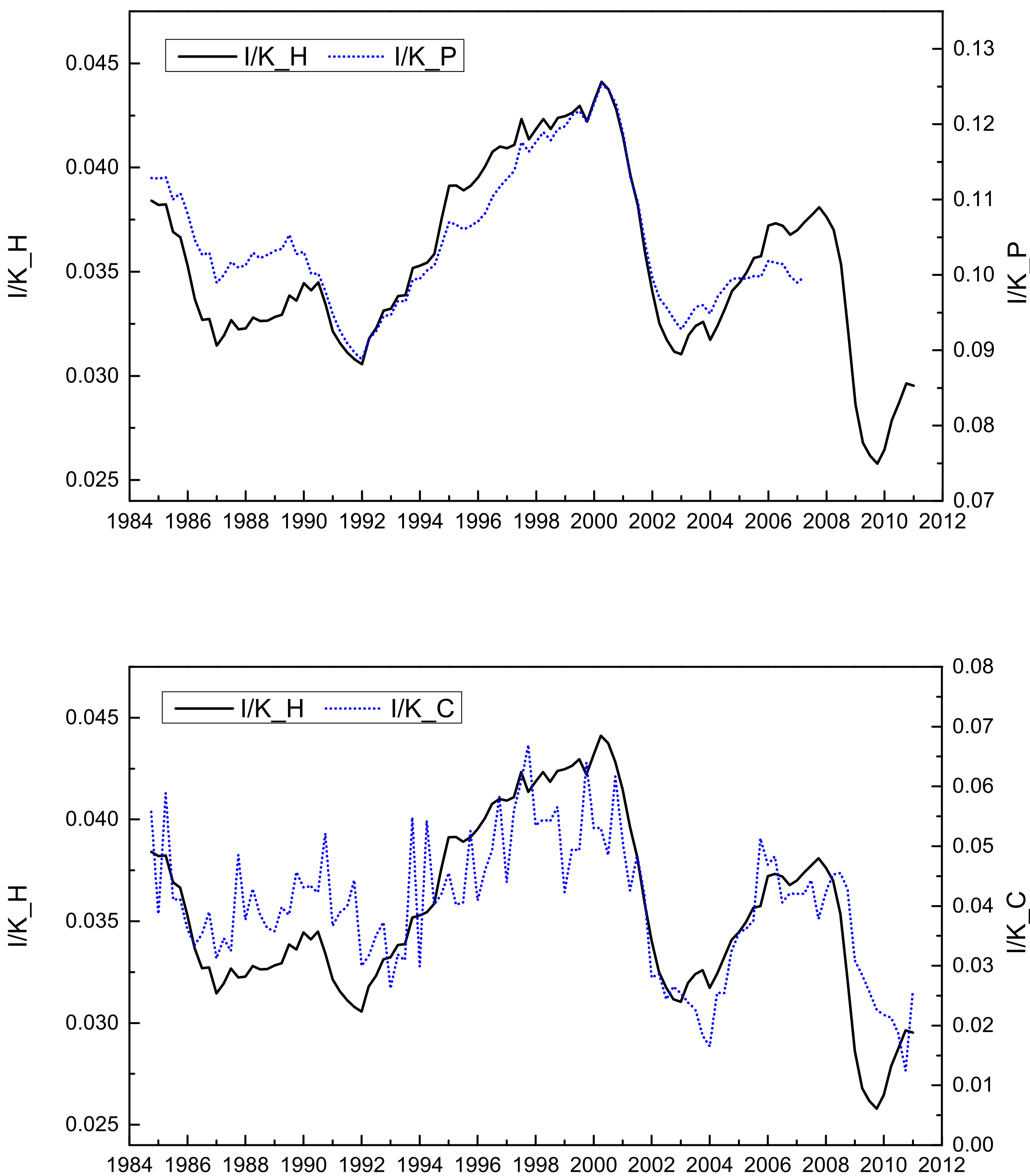

Figure 2. Alternative q measures

$q^{classic}$_H is constructed as in Hall [2001]. $q^{classic}$_P and q^{bond} are from Philippon [2009]. q^{merton} is the aggregate market value of firms net of inventories, scaled by aggregate replacement cost of capital net of depreciation. Replacement cost of capital net of depreciation is the book value of firm's net total property, plant and equipment.

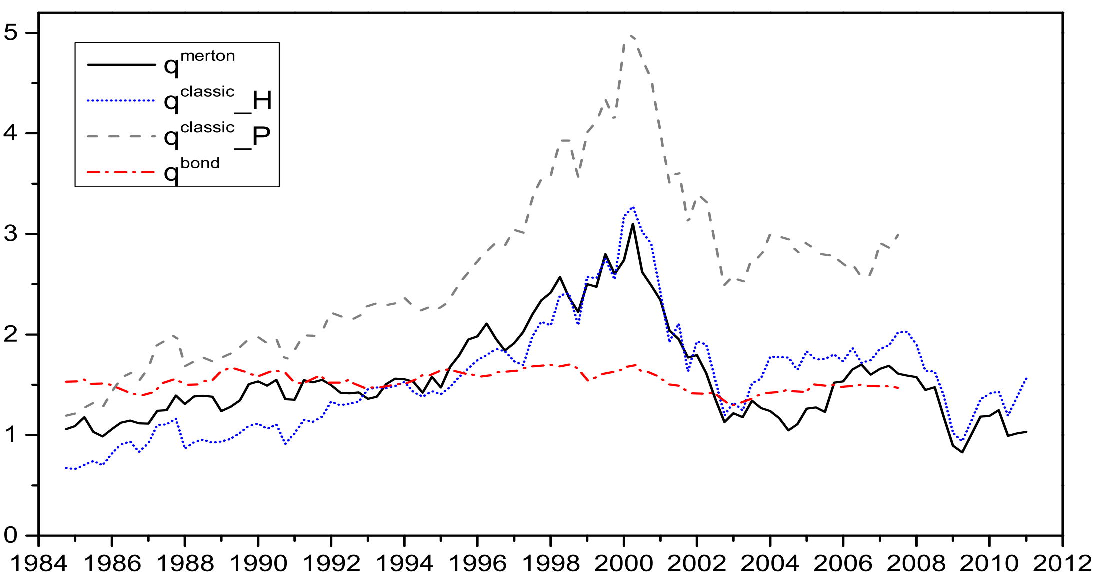

Figure 3. Investment vs. alternative q measures

Investment over replacement cost of capital net of depreciation I/K_H and $q^{classic}$_H are constructed as in Hall [2001]. q^{bond} is from Philippon [2009]. q^{merton} is the aggregate market value of firms net of inventories, scaled by aggregate replacement cost of capital net of depreciation. Replacement cost of capital net of depreciation is the book value of firm's net total property, plant and equipment. (a) Investment vs. q^{merton}; (b) Investment vs. q^{bond}; (c) Investment vs. $q^{classic}$_H.

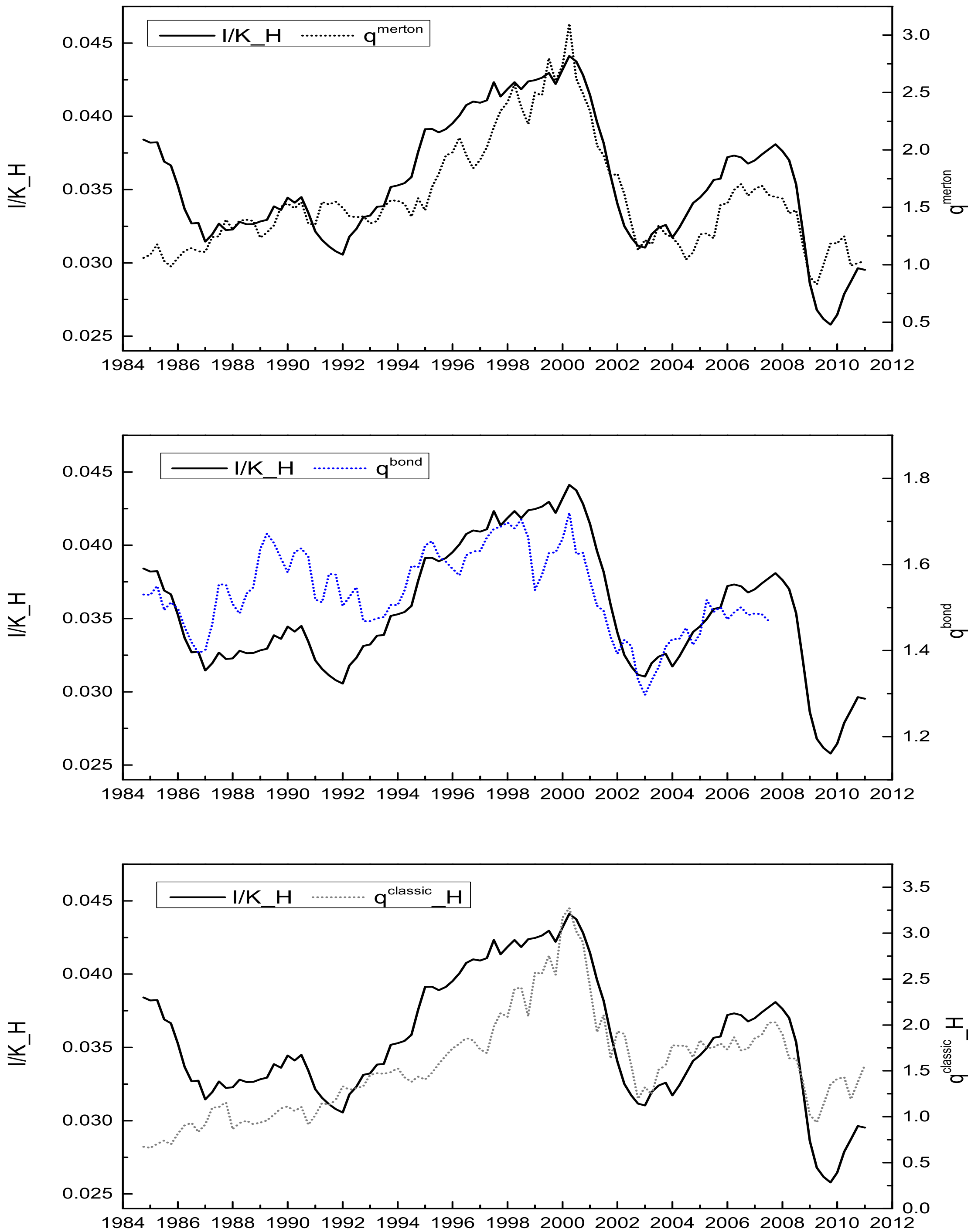

Figure 4. Investment vs. other factors

Investment over replacement cost of capital net of depreciation I/K_H is constructed as in Hall [2001]. Book leverage and credit spread are constructed as in Philippon [2009]. Idiosyncratic volatility is calculated as in Goyal and Santa-Clara [2003]. (a) Investment vs. Book Leverage; (b) Investment vs. Idiosyncratic volatility; (c) Investment vs. Spread.