Convergence in Corporate Investments^{*}

Vito D. Gala and Brandon Julio[†]

January 2011

ABSTRACT

We provide robust empirical evidence of conditional convergence in corporate investments among US firms. Small firms have significantly higher investment rates than large firms even after controlling for standard empirical proxies of firm investment opportunities and financial status, such as Tobin's Q and cash flow measures. The inclusion of a firm's initial size in a traditional Tobin's Q investment regression is at least as economically and statistically important as the inclusion of cash flow measures in explaining corporate investment dynamics. This finding is robust to measurement errors, sample selection, nonlinear specifications of the investment regression, different estimation horizons, and different proxies of investment opportunities and financial status. We also document convergence in corporate investments in other countries around the world. Accounting for the size dependence in standard empirical investment specifications substantially improves the explanatory power of corporate investments dynamics. Moreover, the empirical evidence suggests that firm size improves the measurement of firms' true investment opportunity set rather than reflecting differences in firms' financial constraints.

^{*}We thank John Cochrane, George Constantinides, Ian Cooper, Joao Gomes, Lars Hansen, John Heaton, Christopher Hennessy, Samuli Knupfer, Monika Piazzesi, Henri Servaes, Pietro Veronesi, Vikrant Vig and seminar participants at London Business School, The University of Chicago, Booth School of Business, and the University of Amsterdam for helpful comments and suggestions. All errors are our own.

[†]Department of Finance, London Business School, Regent's Park, London NW1 4SA, United Kingdom; e-mail: vgala@london.edu; bjulio@london.edu. Part of this research was developed while Vito D. Gala was at The University of Chicago, Booth School of Business.

I Introduction

In this paper we examine the growth dynamics of firms. In particular, we provide an empirical investigation of the relationship between firm size and investment rates. An important question in the industrial organization and investment literature is whether small firms grow faster than large firms. More importantly, whether there is any relationship between investment and size even after accounting for differences in traditional measures of a firm's investment opportunities and/or financial status. These questions are central to understanding the investment dynamics at the firm level and have implications for aggregate investment and economic growth. However, the role of firm size in growth dynamics has not yet received much attention in the corporate investment literature, where the debate on interpretation of cash flow sensitivities has taken center stage for the past few decades.

Using a sample of publicly traded firms in the United States between 1962 to 2006, we find that small firms grow significantly faster than large firms. The investment rate of firms in the bottom decile of the size distribution in the United States averages about 45.3% per annum, and is about 2.3 times that of firms in the top size decile. This finding, which we refer to as *unconditional* convergence, is well-known in the empirical industrial organization literature as a violation of Gibrat's Law (1939), and at first glance not surprising in light of the existing models of firm growth and corporate investments since small firms on average have larger values of Tobin's Q .

There are various reasons that may explain such an inverse growth-size relation. For instance, firm size may be proxying for a firm's future investment opportunities and/or financial status that is not captured by the usual proxy variables. However, that small firms grow faster than large firms even after accounting for heterogeneity in their investment opportunities and/or financial status is rather interesting in the context of standard investment models. We unveil evidence of *conditional* convergence in corporate investment rates: a firm's investment

rate is inversely related to its size (as measured by its beginning-of-period capital) even after controlling for factors known to affect a firm's optimal investment policy such as Tobin's Q and cash flow measures, among others.

The evidence of conditional convergence is both statistically and economically meaningful. In all cases and samples, the coefficient estimates are significant at the one percent level. In economic terms, our baseline results suggest that a one-standard deviation increase in a firm size above its average value leads to a 10.9% investment reduction relative to its average investment rate. For comparison, a one-standard deviation increase in Tobin's Q above its average value leads to a 3.8% investment increase relative to its average investment rate, and a one standard deviation increase in cash flow above its average value leads to a 4.7% investment increase relative to its average investment rate. Thus, the economic relevance of variation in firm size is at least as important as that in Tobin's Q and cash flow rates. We also find that the inclusion of firm size to traditional Tobin's Q /cash flow investment regressions significantly increases the explanatory power. In addition, we find that after including firm size as a control variable in investment regressions, the well-known negative relationship between investment rates and leverage disappears. To the best of our knowledge, most of the existing models in the literature allow no explicit role for the size dependence once controlling for Tobin's Q and cash flows.

The finding of *conditional* convergence is robust to choice of empirical proxies of investment opportunities and financial status, different lag structures, time periods, sample selection, nonlinear specifications of the investment regression, and measurement errors. We also find that the relationship between firm size and investment is more robust to possible measurement errors in the proxies for investment opportunities than is the relationship between investment and cash flows. We further provide out-of-sample evidence by employing corporate investment data from several countries outside of the United States. In each of the countries we

examine, we find a strong, negative relationship between beginning-of-period capital and investment rates.

We investigate whether there is any relationship between estimated rates of convergence and a firm's financial status, as measured by the two most prominent empirical measures, namely the Kaplan-Zingales (1997) and Whited-Wu (2006) indexes. We further investigate whether firm size is capturing some aspects of a firm's true unobservable investment opportunity set or financial status. The empirical evidence suggests no relation between conditional convergence and a firm's financial status. Hence, the hypothesis that firm-level conditional convergence is capturing some aspect of a firm's investment opportunity set that is not captured by the standard empirical proxies, namely average Tobin's Q and cash flow, seems more plausible.

It is well known that under the standard Hayashi (1982) conditions of linear homogeneity in a firm's profit function, average Tobin's Q is identical to marginal Q . More generally, Abel and Eberly (1994) show that homogeneity of a firm's profit of any degree in investment and capital makes Tobin's Q proportional to marginal Q and hence a sufficient statistic for firm investment decisions. Various violations of this condition including among others investment irreversibility, pure fixed costs, and time-to-build may drive a wedge between the "observable" average Q and the unobservable marginal Q , thus, leading to an omitted variables problem in empirical specifications of investment. In this context, our findings suggest that conditional convergence may be capturing some aspects of a firm's decreasing technological returns-to-scale. We then investigate whether there is any relationship between the estimated rate of convergence and the degree of technological returns-to-scale in capital. According to a neo-classical model of growth (Solow (1956)) and the convergence literature in macroeconomics (Barro and Sala-i-Martin (1992) and Sala-i-Martin (1996), among others), the degree of convergence should be negatively related to the degree of technological returns-to-scale in capital.

The empirical evidence at the industry level documents the existence of such a negative relationship. Hence, our findings suggest that firm size improves the measurement of a firm's true investment opportunity set.

This finding has several implications. First, given the possibility of mis-specification of the standard investment regression model, the empirical evidence suggests that there is a role for firm size in explaining the observed investment behavior of firms, both in the cross-section and over time. Indeed, accounting for the size dependence in the standard empirical investment specification substantially improves the explanatory power of corporate investments dynamics. Second, the existence of convergence in corporate investments has important implications for economic growth and development. Building on the firm level conditional convergence, Gala and Julio (2010) identify the cross-sectional dispersion in firm size as being particularly relevant to explain aggregate investment dynamics along with the traditional aggregate Tobin's Q and cash-flows. Beck, Demirguc-Kunt, Laeven and Levine (2004) show that firm size plays a significant role in the transmission of financial development to economic growth. Indeed, many policy changes and stimulus packages rest on the assumption that small firms play a special role in economic growth¹.

This paper contributes to the large literature on corporate investment. The main theoretical work on the theory of investment is in Tobin (1969), Hayashi (1982), Abel and Eberly (2002), Gomes (2001) and Hennessy (2004), among others. Much of the recent theoretical and empirical work in corporate investment has focused on the role of cash flow and financial constraints in investment. Empirical evidence focusing on the importance of cash flow measures in traditional Tobin's Q investment regressions are in Fazzari, Hubbard and Petersen (1988), Whited (1992), Gilchrist and Himmelberg (1995), Kaplan and Zingales (1997, 2000), Cleary (1999). Erickson and Whited (2000) emphasize how cash flow sensitivities can be due

¹A recent example is President Obama's small business jobs bill (HR 5297), which was signed into law in September 2010. The package was intended to boost employment and growth in the wake of the financial crisis and subsequent recession.

to measurement error in Tobin's Q . In these studies, firm size is employed as a sorting variable rather than as an explicit control. Lang, Ofek and Stulz (1996) investigate the role of leverage in corporate investment, showing a negative relationship between growth and leverage. The Tobin's Q /cash flow regression specification has been employed in many papers in corporate finance. Some recent examples include the examination of the effects of pension liabilities (Rauh (2006)), changes in investment around corporate spin-offs (Colak and Whited (2007)), and the efficiency of internal capital markets (Ozbas and Scharfstein (2010)). Stein (2003) provides a detailed survey of the theoretical and empirical corporate investment literature.

Firm size is arguably the most common control variable employed in empirical research. Firm size is used as a control in capital structure studies (Hovakimian, Opler and Titman (2001), Barclay and Smith (1995)), cash holdings (Opler, Pinkowitz, Stulz and Williamson (1999)), payout policy (Fama and French (2001)), and managerial compensation (Jensen and Murphy (1990)), for example. Banz (1981) and Fama and French (1992), among others in the empirical asset pricing literature, have explored the role of firm size in explaining the cross-section of expected stock returns. Despite the popularity and importance of firm size in these empirical specifications, very little work has been done investigating why firm size is important in explaining observed corporate behavior. One recent exception is that of Kurshev and Strebulaev (2007), who investigate theoretically the positive cross-sectional relationship between leverage and firm size. They show that the fixed costs of external financing can give rise to leverage dynamics that produce a role for firm size in leverage. Others, such as Kumar, Rajan and Zingales (2004), have also explored potential determinants of firm size.

Firm size has also played a primary role in the industrial organization literature. Prior studies focusing on the relationship between firm size and growth were spawned by Gibrat's Law (1939), the proposition that firm size and growth are independent. The empirical evidence has overturned the conclusion of Gibrat's Law. Studies by Evans (1987) and Hall (1987) show that

the growth rate of manufacturing firms and the volatility of growth are negatively associated with firm size and age. Firm size and age also play an important role in characterizing the dynamics of job reallocation as documented in Davis, Haltiwanger, and Schuh (1996), who show that the rates of job creation and job destruction in U.S. manufacturing firms are decreasing in firm age and size and that, conditional on the initial size, small firms grow faster than large firms. Existing models of the growth of firms explain these features as arising from learning about the technology or from persistent shocks to the technology. Examples that can account for the dependence of firm dynamics either on size or age are the models studied by Jovanovic (1982), Hopenhayn (1992), Hopenhayn and Rogerson (1993), Campbell (1998), and Campbell and Fisher (2000). More recently, Cooley and Quadrini (2001) introduce financial market frictions in a basic model of industry dynamics with persistent shocks to technology and show how the combination of persistent shocks and financial frictions can account for the simultaneous dependence of firm dynamics on size (once one controls for age) and on age (once one controls for size). We add to this literature by providing empirical evidence of conditional convergence in corporate investment rates: a firm's investment rate is negatively related to its size even after controlling for factors known to affect a firm's optimal investment.

The remainder of this paper proceeds as follows. Section II introduces the concepts of unconditional and conditional convergence and motivates the empirical specification. Section III describes and summarizes the data employed in the empirical analysis and presents our main empirical results on the relationship between firm size and investment rates. Section IV presents a battery of robustness tests. Section V concludes.

II Convergence

While in the economic literature the concept of convergence is typically applied to countries or regions within countries, these same notions of convergence can generally be applied to any economic unit. In this section, we adapt these notions to investigate convergence of firms' growth within a country. Building upon the existing investment literature, we focus on corporate investment rates as a measure of a firm's growth.

II.1 β -Convergence

The notion of β -convergence relates to the mobility of different firms within the given distribution of firm size. The basic idea of β -convergence, which follows directly from the neo-classical approach to growth (Barro (1991), Baumol (1986), Barro and Sala-i-Martin (1992), Mankiw et al. (1992), and Sala-i-Martin (1996), among others), requires a firm's growth rate to be positively related to the distance between a firm's current capital stock and its own optimal value. The literature distinguishes two types of β -convergence: unconditional (or absolute) and conditional.

II.1.1 Unconditional β -Convergence

We say that there is unconditional β -convergence if small firms tend to grow faster than large ones. We employ the following regression to test for unconditional β -convergence

$$\frac{I_{i,t}}{K_{i,t-1}} = \beta_0 + \beta_1 \log(K_{i,t-1}) + \varepsilon_{i,t}, \quad (1)$$

where $I_{i,t}$ is investment in property, plant and equipment for firm i in year t , $K_{i,t-1}$ is the beginning-of-year capital stock for firm i , and $\log(K_{i,t-1})$ is the natural logarithm of a firm's

capital stock in year $t - 1$. Then, we have unconditional β -convergence when $\beta_1 < 0$. Unconditional β -Convergence at the firm level can also be interpreted as a specific violation of Gibrat's Law or Law-of-Proportionate Effects - i.e. independence between a firm's growth and its size.

II.1.2 Conditional β -Convergence

Unconditional β -convergence simply requires that small firms grow faster than large ones regardless of differences in the determinants of their own optimal size or investment rate. In fact, unconditional β -convergence relies on the assumption that the only difference among firms lies in their initial levels of capital. However, firms may differ in their levels of technology, the competitive environment in which they operate, structure of corporate governance, access to external financing and other factors affecting a firm's optimal size and investment rate. The notion of conditional β -convergence accounts for differences in the determinants of a firm's optimal size and investment rate. If all firms share the same optimal size, then the two forms of convergence coincide.

We say that there is conditional β -convergence if small firms tend to grow faster than large ones holding constant the optimal size of each firm. We test for conditional β -convergence by augmenting the regression in (1) as follows

$$\frac{I_{i,t}}{K_{i,t-1}} = \beta_0 + \beta_1 \log(K_{i,t-1}) + \theta X_{i,t-1} + \varepsilon_{i,t}, \quad (2)$$

where $X_{i,t-1}$ includes variables that proxy for a firm's optimal size and investment rate. If the estimate of β_1 is negative once $X_{i,t-1}$ is held constant, then we say that the data set exhibits conditional β -convergence.

III Empirical Results

In this section we describe the data used in the analysis and the methods for constructing our various samples. We then conduct formal tests for the presence of convergence and investigate various reasons for why size matters in investment regressions.

III.1 Data

We construct three samples of firms for the empirical analysis. The overall or full sample of firms is taken from the combined annual research, full coverage, and industrial COMPUSTAT files for the years 1962 to 2006. We omit utilities (SIC 4900–4999) and financial firms (SIC 6000–6999) from the sample. We keep all firm-years in our main sample that have non-missing information available to construct the primary variables of interest, namely investment in property, plant and equipment, total capital (net property, plant and equipment), book value of total assets, market value of assets (book value of assets plus the market value of common stock minus the book value of common stock), earnings before extraordinary items, depreciation, stock price at the fiscal year close, and the number of common shares outstanding. We deflate capital expenditures and net property, plant and equipment by the deflator for non-residential investment from the NIPA tables. The remaining data items are deflated using the consumer price index. To ensure that our measure of investment captures the purchase of property, plant and equipment, we eliminate any firm-year in which a firm in the sample made a major acquisition. We then trim the ratio variables (investment rates, Q , cash flow rate) at the 1st and 99th percentiles. This procedure yields a sample of 130,108 firm-years representing 13,986 different firms. We refer to this sample as the “full” sample of firms.

To deal with potential concerns related to entry, exit, and mergers and acquisitions, we also construct a second sample of firms in a balanced panel. To be included in the balanced sample,

a firm must have sufficient data available to construct Tobin's Q , investment, cash flow, and capital stock for every year from 1980 to 2006. In addition, to ensure that our measure of investment captures purchases of property, plant and equipment, we eliminate any firm that may have made a major acquisition during the sample period. These criteria yield a sample of 9,180 firm-years composed of 340 firms that have data available in each of the 27 years in the sample period.

Our third sample is composed of international firm level data from Thomson Financials Worldscope database. Worldscope provides the broadest coverage of international data, covering companies in more than 50 developed and emerging markets and accounting for more than 96 percent of the market value of publicly traded companies across the globe. We use data on firms from Australia, Brazil, Canada, France, Germany, Japan, South Korea and the United Kingdom for our international sample as these eight countries have the widest coverage for non-US firms in the Worldscope database. We keep all firm-years in each of these countries with non-missing data for investment rates, Tobin's Q , cash flow and net property plant and equipment. The international sample has 62,745 firm-years composed of 10,839 firms over the period 1980 to 2005.

The four main variables used in this study (investment, Tobin's Q , cash flow, and firm size) are calculated as follows. Investment is defined as capital expenditures in property, plant and equipment scaled by the beginning-of-year capital stock. The capital stock is defined as net property, plant and equipment. Tobin's Q is defined as the market value of assets scaled by the book value of assets. Cash flow (CF) is calculated as the sum of end-of-year earnings and depreciation scaled by the beginning-of-year capital stock. Finally, firm size is the natural logarithm of the beginning-of-year capital stock for firm i . Table I summarizes various firm characteristics for the full sample, balanced sample and international sample of firms.

III.2 Investment Rates by Size, Tobin's Q and Cash Flow Portfolios

We begin our examination of the relationship between firm size and investment by allocating each firm-year into a size portfolio. Each year, the distribution of firms is divided into size deciles. The decile breakpoints are calculated and the portfolios are rebalanced each year. We then calculate an equal-weighted average of investment rates for each size decile. We repeat this exercise for both the full and balanced samples of firms. Table II reports the mean investment rates for each size decile. The mean investment rate for the smallest decile in the full sample is 0.453. The investment rate for firms in the smallest decile is 2.3 times that of the mean for firms in the largest size decile. The mean investment rate is declining monotonically from the smallest size decile to the largest decile.

A similar monotonic relationship between size and mean investment rate exists in the balanced panel, as reported in Panel B of Table II. Despite the lower variation in firm size in this sample due to the method of construction, the mean investment rate for firms in the smallest decile, 0.333, is 1.9 times larger than the mean investment rate for the firms in the largest size decile. The monotonic, negative relationship between size deciles and investment rates in these two samples provides preliminary evidence of unconditional convergence among the firms in our sample.

To get a first look at conditional convergence, we perform two-way sorts on size and the traditional determinants of corporate investment. We also sort by Tobin's Q , a proxy for a firm's future investment opportunities. Panel A of Table III summarizes the variation of average investment rates across the intersection of five size and Tobin's Q quintiles. Each firm is allocated annually across 5 x 5 quintiles of the joint size - Tobin's Q empirical distribution. We then take an equally-weighted average of the investment rates in each of the 25 portfolios. Across all Tobin's Q quintiles the pattern in average investment rates shows a monotonic negative relation with size. This relation is statistically and economically significant. In the lowest

Tobin's Q quintile, average investment rates fall from 29.7% for the smallest size quintile to 16.6% for the largest. In the highest Tobin's Q quintile, average investment rates fall from 56.4% for the smallest size quintile to 27.9% for the largest. This pattern is consistent with the negative relationship between investment rates and size in the conditional sense as we see a strong negative relationship between size and investment across all of the Tobin's Q quintiles.

Panel B of Table III reports mean investment rates where portfolios are formed on size and the cash flow rate (cash flow over beginning of period capital). Across all cash flow rate quintiles the pattern in average investment rates confirms a monotonic negative relation with firm size. As in Panel A, this relation is statistically and economically significant. In the lowest cash flow rate quintile, average investment rates fall from 28.2% for the smallest relative size quintile to 14.1% for the largest. In the highest cash flow quintile, average investment rates fall from 58.6% for the smallest size quintile to 36.0% for the largest. This is suggestive of conditional convergence as the monotonic relationship holds within each of the cash flow quintiles. We now turn to formally testing the convergence hypothesis in a regression framework.

III.3 Unconditional Convergence

We begin by testing for unconditional convergence among our sample of US firms. Table IV reports the estimation results for various specifications of the investment regression in equation (1). The first and second columns present results without and with year dummies, respectively. The results provide strong evidence of unconditional convergence, that is, smaller firms grow faster than large firms. The magnitude of the coefficient estimate is about -0.0304 in the full sample of firms. This magnitude is quite large in economic terms, as a one standard deviation increase in the log size of a firm leads to an average decrease in its investment rate of about 7.1% per annum. The inclusion of year dummies has a negligible impact on the rate of convergence estimate.

One major concern with employing the full sample is that the estimates of unconditional convergence may be biased by entry and exit of firms. That is, when a firm enters the sample, they might have relatively high growth rates and small capital, while firms that exit tend to have very low growth rates. To the extent that entry and exit are correlated with a firm's size, the coefficients may be biased. To address this concern, we estimate the same specification on the balanced panel of firms. The survivor bias imposed on this sample will ensure that the sample is free of the potential biases arising from entry and exit.

Panel B of Table IV reports the estimates from the balanced sample of firms. Our tests confirm the presence of unconditional convergence in the balanced sample, suggesting that the previous results are not driven by entry and exit in the full sample. A one-standard deviation increase in a firm's log size dampens on average a firm's investment rate by about 4.3% per annum.

III.4 Conditional Convergence

The fact that firm size and investment are negatively related may not seem surprising at first glance in light of the existing corporate investment literature. It might be that firms' heterogeneity in investment opportunities and financial status are indeed driving the convergence results. Indeed, small firms tend to have higher values of Tobin's Q compared to large firms and will therefore have higher investment rates. We now test for the presence of conditional convergence, or the notion that small firms grow faster than large firms even after controlling for investment opportunities and financial status.

The simplest approach to control for unobserved time invariant firms heterogeneity is to include a firm fixed effect to the baseline unconditional convergence regression specified in equation (1). As shown in the first two columns of Table V, the negative relationship between firm size and investment remains unaffected. With firm fixed effects, a one-standard deviation

increase in firm size above its average value leads to a 23.4% investment reduction relative to its average investment rate.

In order to account for time-varying firm heterogeneity, we test for conditional β convergence by estimating the following specification:

$$\frac{I_{i,t}}{K_{i,t-1}} = \alpha_i + \beta_1 \log K_{i,t-1} + \beta_2 Q_{i,t-1} + \beta_3 \frac{CF_{i,t-1}}{K_{i,t-2}} + \varepsilon_{it},$$

where α_i denotes the firm fixed effect and the coefficient, β_1 picks up the convergence effect, conditional on Tobin's Q and cash flows. Table V reports the estimation results for both the full and balanced sample of firms. Across all specifications, the coefficient on the firm size is negative and statistically significant, thus providing evidence of conditional convergence in our samples.

Furthermore, specifications (3) and (4) in Table V give us an idea of how much the explanatory power of a traditional Tobin's Q investment regression improves when adding firm size. In Panel A, we see that the adjusted R-squared increases from 6% in the investment- Q regression to 12% when the log of the firm's capital stock is included. The explanatory power of the regression doubles. The increase in adjusted R-squared is similar in the balanced sample. Panel B of Table V shows that the adjusted R-squared increases to 15% from 9% after the inclusion of firm size in the investment regression.

In Panel A of Table V, specifications (4) through (6), the coefficient estimates of conditional convergence range from -0.0698 to -0.0847, depending on the inclusion of cash flow and year dummy variables. These numbers translate into large economic magnitudes as well. For example, the estimates in the baseline specification with firm and year fixed effects (column (6)) imply that one standard deviation increase in the log size of a firm above its average value leads to an average decrease in investment rates by 18.9% relative to its average investment

rate. For comparison, a one standard deviation in Tobin's Q above its average value leads to an average increase of about 9.3% in a firm's investment rate relative to its average value. Similarly, a one standard deviation increase in a firm's cash flow rate above its average value leads to an average increase of 7.8% in a firm's investment rate relative to its average value.

Panel B of Table V reports the conditional convergence regressions for the balanced sample of firms. The results confirm the presence of conditional convergence. The economic importance of firm size relative to Tobin's Q and cash flow actually increases substantially. With firm and year fixed effects (specification (6)), a one standard deviation increase in a firm size above its average value leads to a 10.9% investment reduction relative to its average investment rate. For comparison, a one standard deviation increase in Tobin's Q above its average value leads to a 3.8% investment increase relative to its average investment rate. Similarly, a one standard deviation increase in cash flow above its average value leads to a 4.7% investment increase relative to its average investment rate.

IV Robustness

The previous section provided strong evidence that small firms grow faster than large firms even after controlling for empirical proxies of growth opportunities and cash flow. This finding of conditional convergence suggests that baseline empirical specifications of corporate investment would ideally include firm size as an explanatory variable. Given the importance of this relationship, we now conduct a large battery of robustness tests to address common problems associated with estimating investment regressions. Table VI reports the estimates from various robustness tests.

Cooley and Quadrini (2001) show how the combination of persistent shocks and financial frictions can account for the simultaneous dependence of firm dynamics on both firm size

and firm age. Thus, one potential problem is that we do not control explicitly for age in the regressions above. The first specification reported in Table VI reports the results when age² is included in the regression. The main result is unchanged—investment rates are negatively related to firm size even after controlling for firm age.

In order to control for the capital intensity of different industries, we first split the sample into manufacturing and non-manufacturing firms. The next two specifications in Table VI report the corresponding investment regression estimates. All coefficients are statistically significant at one percent level. The results are consistent across the two subsamples: firm size is negatively correlated with firm investment rates, even after controlling for investment opportunities and the firm’s financial status. Non-manufacturing firms exhibit a slightly stronger size effect than manufacturing firms.

There are several potential problems in the baseline investment regressions that might undermine the interpretation of the results. Since we measure Tobin’s Q at the beginning of the year in which we measure firm investment, it might be the case that over the year the firm’s investment opportunities or financial status changes. As a consequence, the beginning-of-year Tobin’s Q might only partially reflect future investment opportunities. Specification (4) of Table VI reports the estimates when we add end-of-period Tobin’s Q to the baseline specification in place of lagged Q . Controlling for the change in Q over the investment period has no effect on the results. The coefficient on end-of-period Tobin’s Q is significantly smaller than that on lagged Tobin’s Q . Moreover, the inclusion of end-of-period Tobin’s Q leaves the magnitude and the statistical significance of the coefficient on firm size unaltered. A similar pattern holds for firms’ cash flow rates reported in specification (5), where lagged cash flow is replaced with contemporaneous cash flow. The sensitivity to contemporaneous cash flow

²Similar to Fama and French (2001b) and Pastor and Veronesi (2003), we consider each firm as “born” in the year of first appearance in the database. The firm age is assigned a value of one in the year the firm is born and increases by one in each subsequent year.

is much smaller than that in the baseline regression with lagged cash flows. The negative coefficient on the firm size variable is still significant and large.

The control for future investment opportunities and financial status either using Tobin's Q or cash flow rate might be inadequate if there are lags between when a firm has investment opportunities and when the actual investment is measured. These lags may be due to accounting practices as well as time-to-build considerations. The next three specifications in Table VI include additional lags of investment, Tobin's Q , cash flow rate and size. The coefficient on lagged cash flow rate is wrong-signed and economically negligible. The coefficient on lagged Tobin's Q is statistically insignificant and close to zero. Firm size still preserves its economic and statistical significance in explaining firm investment. We conclude that the timing of our proxy variables for investment opportunities is not an issue.

In specification (9), we include additional control variables for the firm's financial status that are common in the literature. We include the following controls: cash holdings, defined as cash and short-term investment scaled by total assets; leverage, defined as the sum of short-term and long-term debt scaled by total assets; return on assets, defined as net income scaled by total assets; and a dividend payer dummy set equal to one if the firm pays a cash dividend in a given year. We first note that the inclusion of these additional controls does not change the magnitude or significance of firm size in the investment regression. We also see that, controlling for firm size, the estimated coefficients for leverage is not statistically significant.

In specification (10), we investigate whether our results may be generated by model misspecification. To examine whether size in the linear investment regression is picking up some non-linearities in the investment specification, we estimated a polynomial expansion of the baseline model. Specifically, we include squared terms of all the right hand side variables, as well as their interactions. The results in Table VI show that the inclusion of high-order polynomials does not change the magnitude or significance of firm size. While it is impossible to

rule out all types of model mis-specification, we can rule out the possibility that non-linearities in the regression model are driving the results.

IV.0.1 Sample Selection Bias and Additional Robustness

One particularly important potential problem is that our results may be due to the fact that our selected sample is made up of firms that survived long enough to make it into the Compustat sample. It may be that the only firms that survive are those that invest heavily when they are small. It is important to note, however, that the direction of the selection bias is not clear in this case. While the small firm exit effect mentioned above could create a bias in favor of our results, the nature of the Compustat database may actually act as a bias against the result. To see why, consider that a firm will be included in the Compustat database only if it is required by securities law to report its financials annually in a 10-K form. Thus, only firms with publicly traded securities, which are likely to be larger and have higher growth rates, will be included in the sample. We are therefore truncating the size distribution and limiting the variation we observe in firm size, which could act as a bias against our main finding.

Regardless of the direction of the potential bias, it is important to try to control or limit the bias due to sample selection. We take several steps in this effort. The first was to construct the balanced panel of firms which is free from the effects of exit and entry. We showed that our results are not due to entry and exit. In our second approach, we explicitly model the exit decisions of firms in order to test and control for selection bias in our full sample. We employ a Heckman type procedure, where we model the exit decision in the first stage as a function of firm size, Tobin's Q , cash flows, cash holdings, and leverage. We then obtain the inverse Mill's Ratio and include it on the right hand side of the investment regression. In results not reported here³, we find that the coefficients are statistically indistinguishable from

³Available upon request

the investment regression without the control for selection bias. In addition, the coefficient on the inverse Mill's ratio is small and statistically insignificant, suggesting that the truncation in our sample due to firm exits is not driving our results.

We consider, but do not report for brevity, a number of additional robustness tests: (1) we run investment regressions over different sub-samples; (2) to reduce the influence of outliers we deflate investment and cash flow by total assets rather than capital; (3) we trimmed relevant firm variables at different percentiles of their unconditional distribution; (4) we include firms with negative investments and firm-years observations with large acquisitions. The main results are statistically robust. In addition, we obtain coefficient estimates consistent in terms of magnitude and statistical significance across alternative estimation methodologies including (1) OLS with firm and year fixed effects estimated by first differencing the actual observations, and (2) Fama-MacBeth regressions.

IV.1 Potential Bias from Measurement Error

Another potential concern with the interpretation of the tests for conditional convergence is that we are using a noisy proxy for Tobin's Q . If the measurement error in our measure of Q is correlated with firm size, there could be a bias in our estimates. In our first approach to dealing with potential measurement error in our proxy for Tobin's Q , we employ a classical errors-in-variables methodology by instrumenting for Tobin's Q . We use three sets of instruments. As the first instrument, we use firm age. The use of firm age as instrument for Tobin's Q is based on their sizable pairwise correlation (-0.30) and the likely absence of correlation between age and measurement error in Tobin's Q . In the second case, we use age and lagged cash flow to instrument for Tobin's Q . Finally, we use firm age, lagged cash flow, and lagged Tobin's Q as instruments for Tobin's Q . The results of the instrumental variables estimation are reported in

the first three columns of Table VII. In all three cases, the magnitude and statistical significance of the firm size is virtually no different from previous results.

As a second approach, we investigate whether the quality of our proxy for Tobin's Q can explain the consistently negative coefficient we obtain on firm size in the investment regressions. To test whether measurement error is driving the sign of the coefficient on firm size, we employ the methodology of Erickson and Whited (2005). This method allows a researcher to draw inferences about the signs of coefficients in the presence of a mismeasured regressor. The last column of Table VII reports the results of the reverse regression in the methodology of Erickson and Whited (2005). We see that the sign on firm size in the reverse regression maintains its negative sign, suggesting that the possible measurement error in our proxy for Tobin's Q is not responsible for the negative sign of the coefficient in the investment regression. Thus, this test implies that our result is robust to measurement error in Tobin's Q . It is interesting to note that the sign on the cash flow coefficient switches from positive to negative in the reverse regression, suggesting that the cash flow sensitivity of investment is sensitive to measurement error in Q .

IV.2 Convergence over Longer Time Horizons

We also estimate rates of conditional convergence over different time horizons, short (2 years), medium (5 years), and long (10 to 20 years). To accomplish this, we estimate regressions of the form

$$\left(\frac{1}{j}\right) \log \left(\frac{K_{i,t}}{K_{i,t-j}} \right) = \alpha_i + \beta_1 \log K_{i,t-j} + \beta_2 Q_{i,t-j} + \beta_3 CF_{i,t-j} + \gamma_t + \varepsilon_{it}, \quad (3)$$

where j indexes the horizon period. Thus, we regress annualized capital stock growth from year $t - j$ to year t firm size, Tobin's Q and cash flow rate in year $t-j$. Table VIII shows that estimates of the rates of convergence are largely independent of the estimation horizon.

IV.3 International Evidence

We conclude the empirical examination of conditional convergence by conducting an out-of-sample test. We estimate the investment regression for eight other countries around the world to investigate whether the results related to conditional convergence are unique to the US sample of firms. From the Worldscope database, we obtain firm level data for Australia, Brazil, Canada, France, Germany, Japan, South Korea, and the United Kingdom. The variables are constructed in the same manner as for the US firms.

The investment regressions for the international sample are reported in Table IX. We see that in each of the eight countries, there is significant evidence of conditional convergence. The coefficient estimates on firm size are roughly similar in magnitude to those obtained using US data, although they are significantly higher in France and Germany. Thus, we conclude that the evidence for conditional convergence is compelling and robust.

V Financial Constraints or Investment Opportunities

The robust finding of conditional convergence suggests that firm size may be capturing some aspects of two broad determinants of corporate investment. On one hand, firm size may be capturing a firm's financial status, or equivalently a firm's degree of external finance constraints. On the other hand, size may be providing additional information about a firm's true investment opportunities that is not contained in the standard proxies of investment opportu-

nities, such as average Tobin's Q and/or cash flow measures. In this section, we investigate which of these two channels is most plausible.

We first explore whether our estimates of conditional convergence are simply reflecting the degree of external finance constraints that a firm may be facing. This is motivated by the large literature on cash flow sensitivities of investment, which often uses firm size as a sorting variable, where larger firms are thought to be less constrained compared to smaller firms. We investigate whether the estimated rates of convergence depend on the degree of a firm's financial constraints, as measured by the two most prominent measures, the Kaplan-Zingales (1997) KZ index, and the Whited-Wu (2006) WW index. We construct a series of dummy variables based on whether a firm ranks high or low in either of these indices and interact these dummies with the control variables and firm size⁴. We also include the index itself as a control. Thus, the interaction term between the constraint dummy and firm size estimates the difference in convergence rates between constrained and unconstrained firms. Table X reports the results of the investment regressions including the constraint dummy variables. For comparison, specification (1) reports the baseline regression results without the constraints dummy. Specification (2) includes a dummy variable set equal to one if the firm's WW index is less than the median and zero otherwise. Specification (3) includes a dummy variable set equal to one if the firm's KZ index is less than the median and zero otherwise. Specifications (4) and (5) construct two dummy variables, one set equal to one if the value of the respective indices is less than the first quartile of the distribution, and another set equal to one if the value of the index exceeds the third quartile of the distribution.

The results in Table X suggest that the rates of conditional convergence are unrelated to measures of financial constraints. The rate of convergence for high WW index and low WW index firms are statistically indistinguishable. The same results hold when the firms are

⁴For brevity, the interaction terms with Tobin's Q and cash flow as well as the coefficient on the dummy itself are not included in the table, but are available upon request.

sorted by the KZ index. Column (4) shows that the rate of convergence for firms in the top quartile of the WW index is not different from the rate of convergence for firms in the bottom quartile of the index. The results in Column (5) are similar. To the extent that these indices capture the degree of a firm's external finance constraints, the results in Table X suggest that the negative relationship between firm size and investment rates does not reflect differences in financial constraints. Thus, the evidence suggests that the strong relationship between size and investment is most likely related to the measurement of a firm's true investment opportunity set rather than reflecting differences in firms' financial status.

We then explore whether firm size may be capturing additional information about a firm's true investment opportunities that is not contained in the standard proxies including average Tobin's Q and/or cash flow measures. Based on the work by Hayashi (1982) and Abel and Eberly (1994), we know that homogeneity of a firm's profit of any degree in investment and capital makes Tobin's Q proportional to marginal Q and hence a sufficient statistic for firm investment decisions. However, any violation of this condition, including for instance investment irreversibility, pure fixed costs, and time-to-build may drive a wedge between average and marginal Q , leading to an omitted variables problem in empirical specifications of investment. In this context, our findings suggest that conditional convergence may be capturing some aspects of a firm's decreasing technological returns-to-scale not fully captured by standard empirical proxies such as Tobin's Q and/or cash flow.

We investigate whether there is any relationship between the estimated rate of convergence and the degree of technological returns-to-scale in capital across two-digit SIC industries. According to a neoclassical model of growth (Solow (1956)) and the convergence literature in macroeconomics (Barro and Sala-i-Martin (1992) and Sala-i-Martin (1996), among others), the (absolute value of) degree of convergence should be negatively related to the degree of

technological returns-to-scale in capital⁵. The intuition behind this relation stems from the assumption of diminishing returns to capital in the neoclassical production function. The rate of return to capital is large when the stock of capital is small and hence investment rates are expected to be high. In contrast, when the stock of capital is large the rate of return on capital and investment rates are low, growth rates are expected to be low. Thus, the neoclassical model predicts convergence and, as shown in Sala-i-Martin (1996), the rate of convergence is negatively related to the capital share in the production function.

We first estimate the rate of convergence and a proxy for the degree of technological returns-to-scale in capital, θ , from a panel of firms within each industry separately⁶. We then run a cross-industry regression of the rates of convergence on the estimates of technological returns-to-scale in capital. Table XI reports the results. Specification (1) provides evidence of a positive (negative) relation between (the absolute value of) rates of convergence and technological returns-to-scale in capital. Specification (2) includes the average industry depreciation rate and the average growth rate of industry productivity shocks as controls. The results remain basically unchanged. Estimation details for the relevant variables are provided in the Appendix.

The empirical evidence at the industry level confirms the existence of a relationship between the estimated rates of convergence and technological returns-to-scale. Overall, our findings suggest that firm size may be capturing some information about a firm's decreasing technological returns-to-scale not fully captured by standard empirical proxies such as Tobin's

⁵Within a neoclassical growth model with constant-returns-to-scale Cobb-Douglas production function, Sala-i-Martin (1996) provides an approximate relationship between the (absolute value of) rate of convergence (β) and fundamental parameters:

$$\beta = (1 - \alpha)(\delta + n + x),$$

where α is the capital share in the production function, δ is the capital depreciation rate, n is the rate of population growth, and x is the rate of productivity growth.

⁶Under the assumption of no heterogeneity in the demand elasticity across industries, variation in θ identifies variation in the true degree of technological returns-to-scale in capital, α . We maintain this assumption for identification purposes. See Appendix for more details.

Q and/or cash flow, thus improving the measurement of a firm's true unobservable investment opportunity set.

VI Conclusion

A long literature in industrial organization and corporate finance has focused on the determinants of corporate investment dynamics. While the corporate finance literature has focused on the role of Tobin's Q and cash flow as determinants of investment, the industrial organization and growth literature have focused on the role of size in investment. This paper links the two streams of literature and examines whether size dependence, also known as convergence, is important in corporate investment decisions after controlling for the usual proxies for firm investment opportunities and financial status.

The results of the analysis above provide strong evidence that small firms grow faster than large firms even after controlling for growth opportunities and financial status. Indeed, we find that the economic and statistical significance of firm size in investment regressions is at least as important as Tobin's Q and cash flow. The results are robust to controls for selection bias, measurement error in our proxy for Tobin's Q , different measures of investment opportunities and firm financial conditions, different functional forms, different estimation horizons, and across different subsamples. We also investigate eight countries outside of the US and find that conditional convergence is present internationally. Moreover, further empirical evidence suggests that the strong relationship between size and investment is related to the measurement of a firm's investment opportunity set rather than reflecting differences in firm's financial status.

We view these results as having three important contributions. First, these results simply lay out some important facts about the role of size in corporate investment. The negative relationship between firm size and growth, which may seem unsurprising at first glance, becomes

quite important when we see that the relationship holds after controlling for traditional proxies of growth opportunities and financial status of firms. Most of the existing models based on homogeneity assumptions in the literature allow no explicit role for the size dependence once controlling for Tobin's Q and cash flows. Thus, we hope that the role of firm size is examined more fully in the future. The second contribution is a methodological one. The empirical evidence suggests that there is a role for firm size in explaining the observed investment behavior of firms, both cross-sectionally and over time. The finding of conditional convergence suggests that baseline empirical specifications of corporate investment would ideally include firm size as an explanatory variable as its inclusion substantially improves the explanatory power of investment regressions. Finally, as shown in Gala and Julio (2010), while these facts related to the dynamics of corporate investment are very important on their own merits, they also have important implications for aggregate investment dynamics.

Appendix

In this section, we discuss the measurement of decreasing returns-to-scale in capital and the details and robustness of estimation for the profit function. Our methodology follows Cooper and Haltiwanger (2006).

We assume that each productive unit has a Cobb-Douglas production function with constant-returns-to-scale in all inputs of production given by $y = AK^\alpha L^{1-\alpha}$. A denotes the productivity shock, K is physical capital, L is the variable factor(s), and ω is the price of the variable factor(s). The equations that follow are based on one variable factor for expositional purposes but extend easily to multiple variable factors. We furthermore assume that the inverse demand function with constant elasticity is given by $p = y^{-\eta}$ with corresponding revenue function of $R(y) = y^{1-\eta}$. Optimization of the profit function over the variable factor

$$\max_L [R(y) - \omega L]$$

yields a revenue function $R(K, \tilde{A})$ and profit function $\Pi(K, \tilde{A})$ given by

$$R(K, \tilde{A}) = \tilde{A} K^\theta$$

and

$$\Pi(K, \tilde{A}) = (1 - \tilde{\phi}) \tilde{A} K^\theta$$

where $\tilde{A} = [A^{(1-\eta)} (\tilde{\phi}/\omega)^{\tilde{\phi}}]^{1/(1-\tilde{\phi})}$ reflects both the shocks to the production function and variations in variable factors' costs, $\theta = \alpha(1-\eta)/(1-\tilde{\phi})$ and $\tilde{\phi} = (1-\alpha)(1-\eta)$. The coefficient on K measuring the degree of returns-to-scale in capital (θ) in both the revenue and profit functions is the same. Moreover, the properties of the shocks to revenue and profits are the same up to a factor of proportionality. So the estimation strategy is to estimate θ from either a

log-linear first-differenced profit or revenue regression on the capital stock. The latter seems preferred since there is potentially less measurement error involved. There are a small number of observations with negative measured real variable profits but by construction there are no businesses with negative real revenue. In the analysis in the paper we use the estimate of θ from the real revenue log-linear first-differenced estimation, but this is not critical for the reported results. To obtain the adjusted productivity shocks, $\tilde{A}$, we use the estimate of θ and use the optimized revenue function to infer the shocks.

Real revenues are measured as total sales, deflated by the consumer price index from NIPA. We estimate the revenue function in logs and first differences, where the left hand side is the difference in log sales from t to $t + 1$ and the right hand side is the difference in log scale (net property, plant and equipment) from year $t - 1$ to t . We estimate this regression for all firms in our sample at the 2-digit SIC industry level. For each industry, we obtain an estimate of θ . This estimate is used to infer industry-level productivity shocks by substituting θ in the revenue function and solving for $\tilde{A}$. We then aggregate these estimates at the industry level and calculate the average change in productivity shocks over the sample period. This serves as our baseline estimate for the growth in productivity shocks. Our estimates of technological returns to scale and growth in productivity shocks are employed in the regressions reported in Table XI.

The results are robust to several alternative approaches. We also estimated the technological returns to scale and growth in productivity shocks using aggregated industry-level data. That is, for each 2-digit SIC industry, we sum up total revenues and capital for each firm-year and estimate the parameters in the time series for each industry. In this case, the intercept of the revenue function regression (in differences of logs) serves as the estimate for the growth in productivity shocks. We also estimate the rates of convergence at the industry level rather than at the firm level. The results⁷ are similar regardless of the estimation approach.

⁷Available upon request.

References

- Abel, A.B. and J.C. Eberly, 1994, A Unified Model of Investment Under Uncertainty, *American Economic Review*, Vol. 84, No. 5, pp. 1369–1384.
- Abel, A.B. and J.C. Eberly, 2002, Investment with q and Fixed Costs: An Empirical Analysis, Working Paper, University of Pennsylvania.
- Banz, R. W., 1981, The relationship between return and the market value of common stocks, *Journal of Financial Economics* 9, 3–18.
- Barclay M. and C. Smith, 1995, The maturity structure Of corporate-debt, *Journal of Finance*, 50 (2): 609–631.
- Barro, R.J., 1991, Economic Growth in a Cross Section of Countries, *Quarterly Journal of Economics*, Vol. 106(2), 407-443.
- Barro, R.J. and X. Sala-i-Martin, 1992, Convergence, *Journal of Political Economy*, Vol. 100(2), 223–251.
- Baumol, W. J., 1986, Productivity Growth, Convergence, and Welfare: What the Long-run Data Show, *American Economic Review*, Vol. 76, 1072–85.
- Beck, T. Demircug-Kunt, A., Laeven, L. and R. Levine, 2008, Finance, Firm Size, and Growth, *Journal of Money, Credit, and Banking*, October.
- Burnside, C., 1996, Production function regressions, returns to scale, and externalities, *Journal of Monetary Economics* 37, 177–201.,
- Campbell, J., 1998, Entry, Exit, Embodied Technology, and Business Cycles, *Review of Economic Dynamics*, 1(2), 371–408.
- Campbell, J. and J. Fisher, 2000, Aggregate Employment Fluctuations with Microeconomic Asymmetries, *American Economic Review*, 90(5) 1323–1345.
- Cleary, S., 1999, The Relationship Between Firm Investment and Financial Status, *Journal of Finance*, April, 673-692.
- Colak, Gonul and Toni M. Whited, 2007, Spin-offs, divestitures, and conglomerate investment, *Review of Financial Studies* 20, 557–595.
- Cooper, R. W. and J. C. Haltiwanger, 2006, On the Nature of Capital Adjustment Costs, *Review of Economic Studies* 73, 611–633.

- Davis, S. J., Haltiwanger, J.C., and S. Schuch, 1996, Job Creation and Destruction. Cambridge, MA: MIT Press.
- Diewert, W. and K. Fox, 2008, On the estimation of returns to scale, technical progress and monopolistic markups, *Journal of Econometrics*, 145, 174–193.
- Cooley, T and V. Quadrini, 2001, Financial Markets and Firm Dynamics, *American Economic Review*, vol. 91(5), 1286–1310.
- Eberly, J., S. Rebelo, and N. Vincent, 2008, Investment and Value: A Neoclassical Benchmark, Working Paper.
- Erickson, T. and Toni Whited, 2000, Measurement Error and the Relationship between Investment and Q, *The Journal of Political Economy*, 108: 5. 1027–1057.
- Erickson, T. and Toni Whited, 2005, Proxy-quality thresholds: Theory and applications, *Finance Research Letters*, 2, 121–151.
- Evans, David S., 1987, Tests of Alternative Theories of Firm Growth, *Journal of Political Economy*, vol. 95(4), 657–674.
- Fama, E. and K. French, 2001, Disappearing dividends: changing firm characteristics or lower propensity to pay?, *Journal of Financial Economics*, 60, 3–43.
- Fazzari, Steven, R. Glenn Hubbard, and Bruce C. Petersen, 1988, Financing Constraints and Corporate Investment, *Brookings Papers on Economic Activity*, 1:141–206.
- Gala, V. and B. Julio, 2010, Convergence in Corporate Investments and Aggregate Investment Dynamics, Working Paper, London Business School.
- Gibrat R., 1939, Les Ingalités économiques, Paris: Librairie du Recueil Sirey.
- Gilchrist, Simon and Charles Himmelberg, 1995, Evidence on the role of cash flow for investment, *Journal of Monetary Economics* 36: 541–572.
- Gomes, Joao, 2001, Financing Investment, *The American Economic Review*, 91: 1263–1285.
- Hall, B.H., 1987, The Relationship Between Firm Size and Firm Growth in the US Manufacturing Sector, *The Journal of Industrial Economics*, Vol. 35(4), 583–606.
- Hayashi, Fumio, 1982, Tobin's marginal Q and average Q : A neoclassical interpretation, *em Econometrica*, 50, 215–224.
- Hennessey, Christopher, 2004, Tobin's Q, Debt Overhang and Investment, *Journal of Finance*

Vol. 59(4), 1717–1742.

Hopenhayn, H. and R. Rogerson, 1993, Job turnover and policy evaluation: A general equilibrium analysis, *Journal of Political Economy*, 101, 915–938.

Hopenhayn, H., 1992, Entry, exit, and Firm dynamics in long run equilibrium, *Econometrica*, 60, 1127–1150.

Hovakimian, A., Opler, T. and S. Titman, 2001, The debt-equity choice, *Journal of Financial and Quantitative Analysis*, 36, 124.

Jensen, M. and K.J. Murphy, 1990, Performance pay and top-management incentives, *Journal of Political Economy* 98, 225–264.

Jovanovic, B., 1982, Selection and the Evolution of Industry, *Econometrica* Vol. 50(3), 649–670.

Kaplan, S., Zingales, L., 1997, Do financing constraints explain why investment is correlated with cash flow? *Quarterly Journal of Economics* 112, 169–216.

Kaplan, S., Zingales, L., 2000, Investment-Cash Flow Sensitivities are not Valid Measures of Financing Constraints, *Quarterly Journal of Economics*, 707–711.

Kumar, K., Rajan, R. and L. Zingales, 2004, What determines firm size, working paper, University of Chicago.

Kurshev, A. and I. Strebulaev, 2007, Firm Size and Capital Structure, working paper, Stanford University.

Lang, L., Ofek, E. and R. Stulz, 1996, Leverage, investment, and firm growth, *Journal of Financial Economics*, vol. 40(1), 3–29.

Mankiw, N.G., Romer, D., and D. Weil, 1992, A Contribution to the Empirics of Economic Growth, *Quarterly Journal of Economics*, Vol. 107, 407–437.

Opler, T., Pinkowitz, L., Stulz, R., and R. Williamson, 1999. The determinants and implications of corporate cash holdings. *Journal of Finance*, 52, 346.

Ozbas, Oguzhan and David S. Scharfstein, 2010, Evidence on the dark side of internal capital markets, *Review of Financial Studies* 23, 581–599.

Sala-i-Martin, X., 1996, The Classical Approach to Convergence Analysis, *The Economic Journal*, No. 437, 1019–1036.

Solow, Robert M., 1956, A contribution to the theory of economic growth, *Quarterly Journal*

of Economics, vol. 70, 65–94.

Tobin, J., 1969, A General Equilibrium Approach to Monetary Theory, *Journal of Money, Credit and Banking*, 1, 1529.

Whited, T.M., 1992, Debt, liquidity constraints, and corporate investment: Evidence from panel data, *Journal of Finance* 47, 1425-1460.

Whited, T.M. and G. Wu, 2006, Financial constraints risk, *Review of Financial Studies*, 19, 531–559.

Table I
Summary Statistics

This table reports summary statistics for the primary variables used in this paper. The summary statistics are reported for each of three samples: the full sample of US firms from Compustat, the balanced panel of US firms from Compustat, and an international sample of eight countries (Australia, Brazil, Canada, France, Germany, Japan, South Korea, and the United Kingdom) from the Worldscope database.

Panel A: Full Sample				
Variable	N	Mean	Median	Std. Dev.
Investment	130,108	0.3012	0.2130	0.2978
Q	130,108	1.5497	0.9659	2.9165
Cash Flow	130,108	0.5165	0.3316	0.8891
Firm Size	130,108	3.5622	3.4076	2.3412
Panel B: Balanced Sample				
Variable	N	Mean	Median	Std. Dev.
Investment	9,180	0.2330	0.1956	0.1702
Q	9,180	1.1322	0.8952	0.8447
Cash Flow	9,180	0.4247	0.3265	0.4889
Firm Size	9,180	5.3280	5.2818	2.1815
Panel C: International Sample				
Variable	N	Mean	Median	Std. Dev.
Investment	62,745	0.2452	0.1488	0.3652
Q	62,745	1.0156	0.6775	1.4455
Cash Flow	62,745	0.3770	0.2028	1.9811
Firm Size	62,745	13.0079	12.9197	3.8069

Table II
Investment Rates by Size Deciles

This table reports mean and median investment rates across size deciles. Firm portfolios are formed each year by sorting on firm size and allocating the firm into size deciles. The portfolios are rebalanced each year. After the portfolios are formed, we compute an equal-weighted average of the investment rate, defined as capital expenditures scaled by beginning-of-period property, plant and equipment. The sample period for the full sample of 130,108 firm-years reported in Panel A is 1962 to 2006. The sample period for the balanced panel of 9,180 firms reported in Panel B is 1980 to 2006.

Panel A: Full Sample										
Size Decile	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Mean	0.453	0.377	0.345	0.320	0.298	0.281	0.267	0.247	0.225	0.198
Std. Error	0.004	0.003	0.003	0.003	0.002	0.002	0.002	0.002	0.001	0.001
Panel A: Balanced Sample										
Size Decile	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Mean	0.333	0.276	0.246	0.237	0.225	0.229	0.212	0.199	0.201	0.170
Std. Error	0.010	0.007	0.005	0.005	0.004	0.004	0.004	0.003	0.003	0.003

Table III
Investment Rates by Size, Tobin's Q and Cash Flow Portfolios

This table reports mean investment rates and standard errors for firm portfolios based on independent sorts on Tobin's Q, cash flow, and firm size. Each year, we independently sort by size, Tobin's Q and cash flow and allocated the firms into quintiles. The portfolios are rebalanced each year. We then calculate an equal-weighted average of investment rates, defined as capital expenditures scaled by beginning-of-year property, plant and equipment, for each of the portfolios in the 5×4 size/ Q two-way sorts and the 5×4 size/cash flow two-way sorts. The sample period for the full sample of 130,108 firm-years reported in Panel A is 1962 to 2006.

		Size Quintile				
Q Quintile		K_1	K_2	K_3	K_4	K_5
Q_1	Mean	0.297	0.221	0.199	0.178	0.166
	Std. Error	0.004	0.003	0.002	0.002	0.002
Q_2	Mean	0.336	0.261	0.229	0.207	0.175
	Std. Error	0.005	0.004	0.003	0.002	0.002
Q_3	Mean	0.385	0.314	0.278	0.249	0.206
	Std. Error	0.006	0.004	0.003	0.003	0.002
Q_4	Mean	0.460	0.390	0.339	0.301	0.248
	Std. Error	0.006	0.005	0.004	0.003	0.002
Q_5	Mean	0.564	0.482	0.405	0.345	0.279
	Std. Error	0.006	0.006	0.005	0.003	0.003
		Size Quintile				
Cash Flow Quintile		K_1	K_2	K_3	K_4	K_5
CF_1	Mean	0.282	0.214	0.187	0.173	0.141
	Std. Error	0.004	0.004	0.004	0.004	0.002
CF_2	Mean	0.260	0.210	0.206	0.208	0.184
	Std. Error	0.007	0.004	0.003	0.002	0.001
CF_3	Mean	0.300	0.261	0.259	0.256	0.231
	Std. Error	0.006	0.004	0.003	0.002	0.002
CF_4	Mean	0.374	0.340	0.323	0.301	0.285
	Std. Error	0.006	0.004	0.003	0.003	0.002
CF_5	Mean	0.586	0.522	0.453	0.398	0.360
	Std. Error	0.005	0.005	0.005	0.005	0.007

Table IV
Investment Regressions: Unconditional Convergence

This table reports estimates from regressions of the type:

$$\frac{I_{i,t}}{K_{i,t-1}} = \alpha_0 + \beta_1 \log K_{i,t-1} + \varepsilon_{it},$$

where the left hand side is end-of year capital expenditures scaled by beginning-of-year property, plant and equipment. The right hand side variable, $\log K_{i,t-1}$, is the natural logarithm of total capital for firm i . Standard errors are clustered by firm and are reported in parentheses. The sample period for the full sample of 130,108 firm-years reported in Panel A is 1962 to 2006. The sample period for the balanced panel of 9,180 firms reported in Panel B is 1980 to 2005.

Panel A: Full Sample		
	(1)	(2)
$\log K_{i,t-1}$	-0.0304 [0.0006]***	-0.0305 [0.0006]***
Observations	130,108	130,108
R-squared	0.06	0.08
Year Dummies	No	Yes
Panel B: Balanced Sample		
	(1)	(2)
$\log K_{i,t-1}$	-0.0201 [0.0022]***	-0.0183 [0.0023]***
Observations	9,180	9,180
R-squared	0.07	0.10
Year Dummies	No	Yes

Table V
Investment Regressions: Conditional Convergence

This table reports estimates from regressions of the type:

$$\frac{I_{i,t}}{K_{i,t-1}} = \alpha_i + \beta_1 \log K_{i,t-1} + \beta_2 Q_{i,t-1} + \beta_3 \frac{CF_{i,t-1}}{K_{i,t-2}} + \varepsilon_{it},$$

where the left hand side is end-of year capital expenditures scaled by beginning-of-year property, plant and equipment. The right hand side variables include include a firm fixed effect, α_i , Tobin's Q, cash flow, and $\log K_{i,t-1}$ is the natural logarithm of beginning-of-year total capital for firm i . Standard errors are clustered by firm and are reported in parentheses. The sample period for the full sample of 130,108 firm-years reported in Panel A is 1962 to 2006. The sample period for the balanced panel of 9,180 firms reported in Panel B is 1980 to 2005.

Panel A: Full Sample						
	(1)	(2)	(3)	(4)	(5)	(6)
$\log K_{i,t-1}$	-0.0998 [0.0019]***	-0.1052 [0.0022]***		-0.0847 [0.0019]***	-0.0698 [0.0018]***	-0.0810 [0.0020]***
$Q_{i,t-1}$			0.0410 [0.0010]***	0.0281 [0.0010]***	0.0200 [0.0009]***	0.0319 [0.0011]***
$CF_{i,t-1}$					0.0934 [0.0022]***	0.0879 [0.0021]***
Observations	130,108	130,108	130,108	130,108	130,108	130,108
R-squared	0.09	0.11	0.06	0.12	0.17	0.20
Year Dummies	No	Yes	No	No	No	Yes
Panel B: Balanced Sample						
	(1)	(2)	(3)	(4)	(5)	(6)
$\log K_{i,t-1}$	-0.0627 [0.0043]***	-0.0706 [0.0061]***		-0.0536 [0.0041]***	-0.0401 [0.0039]***	-0.0502 [0.0050]***
$Q_{i,t-1}$			0.0714 [0.0060]***	0.0613 [0.0056]***	0.0452 [0.0063]***	0.0455 [0.0064]***
$CF_{i,t-1}$					0.1032 [0.0190]***	0.0958 [0.0190]***
Observations	9,180	9,180	9,180	9,180	9,180	9,180
R-squared	0.09	0.12	0.09	0.15	0.2	0.22
Year Dummies	No	Yes	No	No	No	Yes

Table VI
Robustness Tests

This table reports robustness estimates from variations of the baseline regression:

$$\frac{I_{i,t}}{K_{i,t-1}} = \alpha_i + \beta_1 \log K_{i,t-1} + \beta_2 Q_{i,t-1} + \beta_3 \frac{CF_{i,t-1}}{K_{i,t-2}} + \gamma_t + \varepsilon_{it},$$

where the left hand side is end-of year capital expenditures scaled by beginning-of-year property, plant and equipment. The right hand side variables include a firm fixed effect, α_i , Tobin's Q , cash flow, and $\log K_{i,t-1}$ is the natural logarithm of beginning-of-year total capital for firm i , and year fixed effects γ_t . Specification (1) adds firm age, defined as the number of years since the first appearance of the firm in the database, as an additional control. Specifications (2) and (3) report the estimates for manufacturing (SIC 2000-3999) and non-manufacturing firms, respectively. Specification (4) replaces lagged Tobin's Q with contemporaneous Tobin's Q , while specification (5) uses contemporaneous cash flows. Specifications (6)–(8) include additional lags of investment, firm size, Tobin's Q and cash flow. Specification (9) includes cash holdings, book leverage, return on assets, and a dividend payer dummy as additional controls. Specification (10) reports the estimates from a polynomial expansion of the investment regressions. All squared and interaction terms are included in the specification, but not reported. Standard errors are clustered by firm and are reported in parentheses. The sample period for the full sample of 130,108 firm-years reported in Panel A is 1962 to 2006.

Table VI
Robustness Tests

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
$\log K_{i,t-1}$	-0.0502 [0.0050]***	-0.0526 [0.0060]***	-0.0509 [0.0101]***	-0.0453 [0.0050]***	-0.0596 [0.0062]***	-0.0558 [0.0047]***	-0.0502 [0.0051]***	-0.0431 [0.0052]***	-0.0506 [0.0050]***	-0.0523 [0.0056]***
$Q_{i,t-1}$	0.0455 [0.0064]***	0.0369 [0.0067]***	0.0576 [0.0095]***		0.0590 [0.0060]***	0.0419 [0.0056]***	0.0504 [0.0071]***	0.0520 [0.0071]***	0.0301 [0.0060]***	0.0720 [0.0104]***
$CF_{i,t-1}$	0.0958 [0.0191]***	0.1290 [0.0136]***	0.0669 [0.0230]***	0.1092 [0.0209]***		0.0620 [0.0167]***	0.1085 [0.0143]***	0.0948 [0.0142]***	0.0797 [0.0169]***	0.2185 [0.0280]***
Firm Age	-0.0061 [0.0153]									
$Q_{i,t}$				0.0323 [0.0067]***						
$CF_{i,t}$					0.0144 [0.0096]					
$I_{i,t-1}$						0.1949 [0.0232]***				
$Q_{i,t-2}$							-0.0071 [0.0056]	-0.0097 [0.0060]		
$CF_{i,t-2}$							-0.0131 [0.0055]**	-0.0128 [0.0054]**		
$\log K_{i,t-2}$								-0.0313 [0.0120]***		
Cash									-0.0707 [0.0288]**	
Leverage									0.0066 [0.0089]	
ROA									0.4115 [0.0461]***	
Dividend Payer									0.0330 [0.0099]***	
Observations	9,180	6,588	2,592	9,173	9,180	8,840	9,162	8,840	9,180	9,180
R-squared	0.22	0.24	0.21	0.21	0.19	0.25	0.22	0.23	0.25	0.27

Table VII
Robustness: Measurement Error

This table reports estimates from regressions of the type:

$$\frac{I_{i,t}}{K_{i,t-1}} = \alpha_i + \beta_1 \log K_{i,t-1} + \beta_2 Q_{i,t-1} + \beta_3 \frac{CF_{i,t-1}}{K_{i,t-2}} + \gamma_t + \varepsilon_{it},$$

where the left hand side is end-of year capital expenditures scaled by beginning-of-year property, plant and equipment. The right hand side variables include a firm fixed effect, α_i , year fixed effects, γ_t , Tobin's Q, cash flow, and $\log K_{i,t-1}$ is the natural logarithm of beginning-of-year total capital for firm i . Specifications (1)–(3) report instrumental variables estimation results using firm age, lagged Q and cash flow as instruments for Tobin's Q . Specification (4) reports the reverse regression estimates using the methodology of Erickson and Whited (2005). Standard errors are clustered by firm and are reported in parentheses.

	(1)	(2)	(3)	(4)
$\log K_{i,t-1}$	-0.0468 [0.0027]***	-0.0474 [0.0029]***	-0.0390 [0.0022]***	-0.0560 [0.0080]***
$Q_{i,t-1}$	0.0448 [0.0204]**	0.0480 [0.0225]***	0.0404 [0.0036]***	1.1100 [0.1280]***
$CF_{i,t-1}$	0.1519 [0.0114]***	0.1611 [0.0123]***	0.1012 [0.0046]***	-0.5540 [0.0080]***
Observations	9,180	8,840	8,840	9,180
R-squared	0.19	0.19	0.17	0.14
Instruments	Age	Age, $CF_{i,t-2}$	Age, $CF_{i,t-2}$, $Q_{i,t-2}$	

Table VIII
Convergence over Different Time Horizons

This table reports estimates from regressions of the type:

$$\left(\frac{1}{j}\right) \log \left(\frac{K_{i,t}}{K_{i,t-j}} \right) = \alpha_i + \beta_1 \log K_{i,t-j} + \beta_2 Q_{i,t-j} + \beta_3 CF_{i,t-j} + \gamma_t + \varepsilon_{it},$$

where the left hand side is the annualized change in capital stock from year $t - j$ to year t . The right hand side variables include a firm fixed effect, α_i , year fixed effects, γ_t , Tobin's Q, cash flow, and $\log K_{i,t-j}$ is the log of the firm's capital stock in year $t - j$. Standard errors based on the Newey-West estimator are reported in parentheses.

	(1)	(2)	(3)	(4)
	$j = 2$	$j = 5$	$j = 10$	$j = 20$
$\log K_{i,t-j}$	-0.0773 [0.0058]***	-0.0966 [0.0050]***	-0.0910 [0.0039]***	-0.0502 [0.0020]***
$Q_{i,t-j}$	0.0446 [0.0046]***	0.0209 [0.0030]***	0.0020 [0.0016]	-0.0014 [0.0007]**
$CF_{i,t-j}$	0.0442 [0.0175]**	0.0265 [0.0131]**	0.0112 [0.0047]**	-0.0002 [0.0013]
Observations	8,500	7,480	5,780	2,380
R-squared	0.17	0.33	0.48	0.56

Table IX
Conditional Convergence: International Evidence

This table reports estimates from regressions of the type:

$$\frac{I_{i,t}}{K_{i,t-1}} = \alpha_i + \beta_1 \log K_{i,t-1} + \beta_2 Q_{i,t-1} + \beta_3 \frac{CF_{i,t-1}}{K_{i,t-2}} + \gamma_t + \varepsilon_{it},$$

where the left hand side is end-of year capital expenditures scaled by beginning-of-year property, plant and equipment. The right hand side variables include a firm fixed effect, α_i , year fixed effects, γ_t , Tobin's Q, cash flow, and $\log K_{i,t-1}$ is the natural logarithm of beginning-of-year total capital for firm i . Firm fixed effects and year dummies are included in each regression. Standard errors are clustered by firm and are reported in parentheses.

	Australia	Brazil	Canada	France	Germany	Japan	South Korea	United Kingdom
$\log K_{i,t-1}$	-0.0355 [0.0035]***	-0.0124 [0.0061]**	-0.0363 [0.0030]***	-0.0402 [0.0041]***	-0.0426 [0.0049]***	-0.0162 [0.0019]***	-0.0332 [0.0048]***	-0.0338 [0.0016]***
$Q_{i,t-1}$	0.0611 [0.0066]***	0.0327 [0.0197]*	0.0742 [0.0058]***	0.0882 [0.0128]***	0.0807 [0.0129]***	0.0604 [0.0059]***	0.0979 [0.0135]***	0.0585 [0.0031]***
$CF_{i,t-1}$	0.0262 [0.0042]***	0.0532 [0.0115]***	0.0113 [0.0045]**	0.0364 [0.0108]***	0.0332 [0.0063]***	0.0359 [0.0056]***	0.0253 [0.0085]***	0.0223 [0.0027]***
Observations	5,564	1,533	7,931	4,559	2,998	19,241	3,964	18,598
R-squared	0.14	0.44	0.18	0.21	0.23	0.19	0.18	0.17

Table X
Rates of Convergence and Financial Constraints

This table reports estimates from regressions of the type:

$$\frac{I_{i,t}}{K_{i,t-1}} = \alpha_i + \beta_1 \log K_{i,t-1} + \beta_2 \mathbf{X}_{i,t-1} + \beta_3 D_{index} + \theta_1 D_{index} \times \log K_{i,t-1} + \theta_2 D_{index} \times \mathbf{X}_{i,t-1} + \gamma_t + \varepsilon_{it},$$

where the left hand side is the end-of year capital expenditures scaled by beginning-of-year property, plant and equipment. The right hand side variables include a firm fixed effect, α_i , year fixed effects, γ_t , $\log K_{i,t-1}$, the log of the firm's capital stock in year $t - 1$, D_{index} is an indicator variable set equal to one if a particular firm is classified as belonging to a distribution of either the Kaplan-Zingales (1997) KZ index or the Whited-Wu (2006) index, and $\mathbf{X}_{i,t-1}$ is a set of additional control variables, namely Tobin's Q and cash flow. Specifications (2) and (3) set the dummy variable equal to one if the value of the index for a particular firm is below the median of the distribution. Specifications (4) and (5) set one dummy equal to one if the value of the index for a particular firm is below the first quartile and another dummy equal to one if the value of the index exceeds the third quartile of the distribution. Standard errors are clustered by firm and t-statistics are reported in parentheses.

	(1)	(2)	(3)	(4)	(5)
	All Firms	WW Index - Median	KZ Index - Median	WW Index - Quartiles	KZ Index - Quartiles
$\log K_{i,t-1}$	-0.050 (9.98)***	-0.064 (9.82)***	-0.051 (9.49)***	-0.059 (9.60)***	-0.052 (9.45)***
$Q_{i,t-1}$	0.045 (7.12)***	0.054 (5.68)***	0.221 (7.61)***	0.049 (4.09)***	0.166 (6.54)***
$CF_{i,t-1}$	0.096 (5.03)***	0.041 (2.46)**	0.057 (9.32)***	0.083 (7.17)***	0.049 (7.99)***
Low WW $\times \log K_{i,t-1}$		0.008 (1.00)			
Low KZ $\times \log K_{i,t-1}$			-0.000 (0.11)		
WW _{Q25} $\times \log K_{i,t-1}$				-0.011 (1.14)	
WW _{Q75} $\times \log K_{i,t-1}$				-0.012 (1.39)	
KZ _{Q25} $\times \log K_{i,t-1}$					-0.002 (0.42)
KZ _{Q75} $\times \log K_{i,t-1}$					0.001 (0.19)
Observations	9,180	9,180	9,180	9,180	9,180
R-squared	0.22	0.24	0.25	0.25	0.26

Table XI
Conditional Convergence and Technological Returns to Scale

This table reports estimates from regressions of the type:

$$\beta_k = \alpha_1 + \alpha_2 \theta_k + \gamma \mathbf{X}_k + \varepsilon_k,$$

where the left hand side is the industry-level convergence estimate calculated as the coefficient on the log of firm scale on a within-industry investment regression including firm and time fixed effects, Tobin's Q and cash flow. The right hand side variables include the proxy for technological returns to scale, θ_k , and $\mathbf{X}_k$ includes additional control variables, namely the average industry depreciation rate and the average growth rate of industry-level productivity shocks (see Appendix for estimation details). Standard errors are reported in brackets.

	Balanced Sample		Full Sample	
θ_k	0.0981 [0.0409]**	0.0984 [0.0419]**	0.1166 [0.0284]***	0.1206 [0.0246]***
Productivity _k		-0.0328 [0.1178]		0.0644 [0.2510]
Depreciation Rate _k		0.0089 [0.1202]		0.0129 [0.0109]
N	47	47	47	47
R-squared	0.114	0.115	0.152	0.163