New or Used? Investment with Credit Constraints*†

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Abstract

This paper studies the choice between investment in new and used capital. We argue that used capital inherently relaxes credit constraints and thus firms which are credit constrained invest in used capital. Used capital is cheap relative to new capital in terms of its purchase price but requires substantial maintenance payments later on. The timing of these investment cash outflows makes used capital attractive for credit constrained firms. While used capital is expensive when evaluated using the discount factor of an agent with a high level of internal funds, it is relatively cheap when evaluated from the vantage point of a credit constrained agent with few internal funds. We provide an overlapping generations model and determine the price of used capital in equilibrium. Agents with less internal funds are more credit constrained, invest in used capital, and start smaller firms. Empirically, we find that the fraction of investment in used capital is substantially higher for small firms and varies significantly with measures of financial constraints with the predicted sign.

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1 Introduction

Why invest in used capital rather than new capital? We argue that firms which are credit constrained purchase used capital because the timing of the necessary cash outflows is such that used capital relaxes credit constraints. The purchase price of used capital is lower than that of new capital. However unlike new capital, used capital requires substantial maintenance payments down the road. The timing inherent in these cash flows makes used capital more attractive to firms which are credit constrained at the time of investment. By investing in used capital, constrained firms can operate at a larger scale.

Empirically, we find that, indeed, small firms and credit constrained firms invest significantly more in used capital. Used capital comprises more than twenty five percent of capital expenditures for the smallest firms, compared to around ten percent for the largest firms. Moreover, capital expenditures on used capital relative to total capital expenditures are significantly related to empirical measures of financial constraints with the predicted sign. Thus, financial constraints appear to affect the composition of investment, and not just the level. These facts are not only important for understanding used capital markets, but also because of the focus on the investment behavior of small, credit constrained firms in studies of business cycles and economic growth. Since a significant fraction of these firms' investment is in used capital, it is important to consider capital reallocation as well as net new investment in explaining aggregate investment dynamics. Moreover, studying used capital markets may also improve our understanding of the reversibility of investment decisions, which has received considerable attention in the literature.[1]

We develop an overlapping generations model in order to study the decision to invest in new or used capital along with the equilibrium in the market for used capital. New and used capital are perfect substitutes in production, but used capital requires a maintenance payment subsequent to purchase.[2] Agents can only borrow against a fraction of the resale value of capital and differ in their initial endowments of internal funds. We find that agents which have few internal funds are credit constrained, invest in used capital, and start smaller firms. The model hence predicts that the fraction of capital investment comprised by used capital is decreasing in the size of

[1] See, e.g., Abel and Eberly (1994, 1996).

[2] The importance of maintenance costs have been stressed by McGrattan and Schmitz (1999), who find that spending to maintain and repair both equipment and structures averaged 30% of spending on all new physical capital in Canadian data.

the firm and increasing in the extent to which the firm is financially constrained.

In equilibrium, used capital is expensive when valued using the discount factor of an unconstrained firm, but cheap when valued at the discount factor of a constrained firm. The opposite is true for new capital. The variation in the multiplier on the credit constraint introduces a wedge between the valuations of constrained and unconstrained investors. We show that any agent who invests in used capital in fact must be credit constrained. Thus, one can observe how credit constrained a firm is through revealed preference in the choice between new and used capital. The convenience yield used capital provides by relaxing constrained agents' credit constraints pushes up the equilibrium price of used capital so that it becomes expensive for unconstrained agents. Moreover, since capital can be sold as used capital after use in production, the higher equilibrium price of used capital in the presence of constrained agents makes investment in new capital even more attractive to unconstrained agents.

We find empirically that the fraction of investment comprised by used capital is indeed decreasing with firm size and varies significantly with measures of financial constraints with the predicted sign. This is true for capital overall as well as for structures and equipment separately. We use data from the Vehicle Inventory and Use Survey (VIUS) and data from the Annual Capital Expenditures Survey (ACES), which samples nonfarm businesses, both by the Bureau of the Census. We are among the first to use the ACES micro data.[3] We use data from Compustat for financial variables. Owners of smaller vehicle fleets purchase a much larger fraction of their fleet used than those with large fleets.[4] Similarly, the fraction of capital expenditures on used capital is considerably (about five times) larger for businesses with no employees than for businesses with employees. About thirty percent of aggregate used capital expenditures are done by businesses with no employees, while these businesses contribute only about eight percent of aggregate capital expenditures. Moreover, for businesses with employees, the fraction of capital expenditures on used capital decreases across asset size deciles from about 28% in the smallest size decile to about 10% in largest size decile.[5] We argue that, as in our model, smaller businesses are more likely to be credit constrained, and therefore purchase more used capital which in turn relaxes these constraints. We also show that the fraction of investment in used

[3]Becker, Haltiwanger, Jarmin, Klimek, and Wilson (2004) also use this data set and discuss the characteristics of the data in detail as well as many of the issues involved in measuring capital stocks and flows using this data.

[4]See Bond (1983) for similar evidence on used truck tractors.

[5]Oi (1983) discusses related evidence that smaller firms buy more used capital goods.

capital varies significantly with measures of financial constraints with the predicted sign: firms which pay higher dividends (relative to assets), have lower leverage, and have more cash (relative to assets) have a significantly lower fraction of used capital expenditures.

The composition of investment between new and used capital may also be affected by considerations besides financial constraints, such as the firm's need to be able to reverse investment decisions, technological differences across firms, or differences in taxation. Moreover, variation in these firm level variables may be related to firm size. We find that the relationship between the measures of financial constraints, including size, and used capital expenditures is robust to including control variables related to these alternative explanations. Once these controls are included, the explanatory power of firm size can be argued to be due to the ability of firm size to proxy for financial constraints. In our data, there is no significant relationship between the fraction of used capital expenditures and firm age or the variability of sales, when financial variables are included. Similarly, taxes do not appear to have an important effect on the new vs. used decision. Finally, the capital labor ratio and the R&D to sales ratio do not display a significant relationship to the fraction of used capital expenditures. There is however a negative and significant relationship between the sales to employees ratio and used capital expenditures. This may suggest that less productive firms buy used capital or, as we argue, that firms with low sales to employees are financially constrained and hence buy used capital. Thus, while we do not claim that financial constraints are the only consideration for the new vs. used decision, we find that our measures of financial constraints are robust to the inclusion of technological and tax controls. We obtain similar results when we study used capital expenditures for structures and equipment separately.

Differences in factor prices may also give rise to variation in firms' decisions to invest in new vs. used capital. Bond (1983) develops a model with exogenous heterogeneity in factor prices where firms or sectors with low capacity utilization and low labor costs but high capital costs choose used capital since low labor costs and capacity utilization rates are complementary with the associated production downtime. Variation in factor prices is not correlated with how quickly machines can be fixed, or with productivity in maintaining them. In contrast to our paper, the focus in Bond's model, which is static, is on the relative magnitude of maintenance costs, not on the timing of such payments. Factor price variation has been used to understand trade in used capital across countries, where variation in such prices may be considerable, by Sen (1962) and Smith (1976).

Our work is also related to studies of vintage capital, durable goods, and the effects of credit constraints on investment. In standard vintage capital models the choice between new and used capital is determined by preferences for different vintages. Similarly, the choice between high and low quality durables is often modeled using exogenous preferences for quality. The results in this paper shed light on how these preferences over new and used capital, or goods of high and low quality, might be determined by underlying constraints on the investment decision, and hence complements these studies.[6] Moreover, our paper is related to studies of the effects of credit constraints on investment decisions.[7] The results of our model imply that the degree of a firm's credit constraints can be identified through revealed preference in the choice between new and used capital. This is important because although shifts in investment opportunities drive total capital expenditures, it is not clear that they should affect the new vs. used composition of such expenditures.

Finally, this paper is in part motivated by our previous work on capital reallocation (Eisfeldt and Rampini (2005a)).[8] There we find that capital reallocation is procyclical while the benefits of reallocation, in terms of measures of cross sectional dispersion of productivity, seem countercyclical. We conclude that the reallocation frictions must be higher in bad times. Could this be explained by the fact that firms are more credit constrained in bad times? This is not clear since while that would

[6]For vintage capital models, see Benhabib and Rustichini (1991), Cooley, Greenwood, and Yorukoglu (1997), Campbell (1998), and Jovanovic (1998). For models of durable goods markets with exogenous preferences over quality, see, for example, Hendel and Lizzeri (1999) for a dynamic adverse selection model with sorting of new and used goods to heterogeneous consumers, Stolyarov (2002) for a model where goods deteriorate with age and volume varies with vintage, and Berkovec (1985), Porter and Sattler (1999), and Adda and Cooper (2000) for simulated discrete choice models and associated empirical tests in the automobile market.

[7]For a survey, see Hubbard (1998). For empirical tests of constrained and unconstrained firms' investment Euler equations, see Whited (1992) and Bond and Meghir (1994). For models describing the effects of variation in net worth on credit constraints, see Townsend (1979), Gale and Hellwig (1985), and Bernanke and Gertler (1989). For evidence that leverage affects overall investment in the trucking industry, see Zingales (1998). For models and evidence of distortions in durable goods consumption from credit constraints, see, for example, Chah, Ramey, and Starr (1995) and Campbell and Hercowitz (2003). Finally, for a general model of investment with a wedge between the purchase price and sale price of capital in the absence of credit constraints see Abel and Eberly (1994).

[8]For more on the literature on capital reallocation see Eisfeldt and Rampini (2004, 2005a) and papers cited therein.

make it harder for potential buyers to buy used capital it might at the same time make potential sellers more eager to sell since they too are more credit constrained.[9] Thus, one might ask: Who buys used capital? Here we study this question and provide both a theory and evidence that it is the more credit constrained firms who buy used capital. This may then be part of the explanation why there is less capital reallocation in bad times.[10]

The remainder of the paper is organized as follows: In Section 2 we describe our model of new and used capital investment decisions, along with the associated equilibrium in the used capital market. We also present numerical examples to illustrate our results. In Section 3 we discuss the empirical evidence. We conclude in Section 4.

2 Credit Constraints and the Purchase of Used Capital

In this section we consider an economy in which agents can choose between investing in new and used capital in order to study the effect of credit constraints on this choice.

2.1 The Environment

Consider an economy with overlapping generations. Time is discrete and indexed by $t = 0, 1, 2, \ldots$. At each point in time t, a generation with a continuum of agents with measure one is born. Generations live for one period, that is, for two dates. Agents have identical preferences and access to the same productive technologies, but differ in the idiosyncratic endowment of consumption goods that they are born with, i.e., in the amount of internal funds that they have. The preferences of an agent born in generation t are

$$u(c_t) + \beta u(c_{t+1})$$

[9] For evidence that financially constrained firms are more likely to sell assets see Pulvino (1998) and Ramey and Shapiro (2001).

[10] See also Eisfeldt (2004) and Eisfeldt and Rampini (2004) for additional mechanisms which render reallocation frictions countercyclical.

where u is strictly increasing and concave and satisfies $\lim_{c \to 0} u'(c) = +\infty$.[11] At time t, each agent observes his idiosyncratic endowment $e \in \mathcal{E} \subset \mathbb{R}_+$ which is distributed independently and identically with density $\pi(e)$ on $\mathcal{E}$.

At time t, each young agent chooses how much to invest in new and used capital for use in production at time $t+1$. The price of new capital is normalized to 1. Used capital, on the other hand, can be bought at a price p_u, which will be determined in equilibrium. Used capital will turn out to be cheaper than new capital in terms of its purchase price, i.e., $p_u < 1$, in equilibrium, but it requires maintenance one period after it is bought. That is, investment in a unit of used capital at time t, requires payments of p_u at time t and $m_u > 0$ at time $t+1$. New and used capital are assumed to be perfect substitutes in production. Thus, an agent who invest $i_{u,t}$ in used capital and $i_{n,t}$ in new capital will have a total amount of capital $k_t = i_{u,t} + i_{n,t}$. Capital generates output of $f(k_t) = k_t^{\alpha}$, where $\alpha \in (0, 1)$, at time $t + 1$. Capital depreciates at a rate of δ, such that the agent will have $k_{t+1} = (1 - \delta)k_t$ units of capital at time $t + 1$. The agent can sell the depreciated capital at time $t + 1$ as used capital to agents from the next generation. Notice that both new and used capital are sold as used capital after use in production. The idea is that except for the original owner who buys capital new, capital requires maintenance one period after the capital is purchased. Once capital has been previously owned, it is used and it does not matter how many previous owners there were. Notice that our model is consistent with the common perception that the difference between the purchase price and the sale price for new capital is larger than for used capital. Specifically, a unit of new capital is bought at a price of 1 and sold for $p_u(1 - \delta)$ whereas a unit of used capital is bought for p_u and sold for $p_u(1 - \delta)$. However, this does not imply that the user cost of new capital is necessarily higher than the user cost of used capital since used capital requires maintenance whereas new capital does not.

Furthermore, an agent can borrow or save at a rate of return $R = \beta^{-1}$, which we fix exogenously to focus on the equilibrium in the used capital market.[12] An agent

[11] Strict concavity of the utility function is not necessary for our results as long as the production function is concave. Indeed, we could assume linear preferences, i.e., risk neutrality. We discuss below how this can be seen using the marginal rates of transformation as discount rates, rather than marginal rates of substitution.

[12] We could alternatively determine the interest rate R endogenously such that both the used capital market and the credit market clear without affecting our qualitative results. The main difference would be that the discount rate of unconstrained agents would then be one over the equilibrium interest rate $1/R$ rather than β.

can however only borrow against a fraction $0 \leq \theta < 1$ of the resale value of capital and can not borrow against future output. Thus, the agent needs to provide collateral for loans he takes out and the extent of collateralization is limited. This constraint can be motivated by assuming that lenders can only seize a fraction θ of the capital in case of default, which limits how much the agent can credibly promise to repay to that amount.[13] This defines the credit constraint considered here. Agents' investment in used or new capital is constrained by the amount of their initial endowment of internal funds and their limited ability to borrow. Note that $\theta = 0$ is a special case of our model where agents can not borrow at all, neither against output nor against capital. All the results that we obtain in this paper apply to this special case as well.

We consider a stationary equilibrium where the price of used capital p_u is determined such that all the used capital sold by agents in generation t is bought by agents in generation $t+1$. The equilibrium will be stationary in the sense that all aggregate quantities, such as investment, the capital stock, and the volume of trade in used capital are constant across periods. We provide a formal definition of a stationary equilibrium in Section 2.3.

2.2 The Agent's Problem

Consider the problem of an agent in generation t, $t \in \{0, 1, 2, \dots\}$. Since we are studying a stationary model and all generations are identical, we will consider the problem of generation 0 to simplify notation. Taking the price of used capital p_u as given, the agent's problem is one of maximizing utility by choice of consumptions $\{c_0, c_1\}$, investment in used capital i_u and new capital i_n, and borrowing b, given their initial endowment of internal funds e. Specifically, the agent's problem is

$$\max_{(c_0, c_1, i_u, i_n, b) \in \mathbb{R}^2_+ \times \mathbb{R}^3} u(c_0) + \beta u(c_1)$$

subject to

$$c_0 + p_u i_u + i_n \leq e + b \tag{1}$$

$$c_1 + m_u i_u + Rb \leq k^\alpha + p_u k(1 - \delta), \tag{2}$$

where $k \equiv i_u + i_n$,

$$0 \leq i_u, i_n, \tag{3}$$

[13] See Hart and Moore (1994) and Kiyotaki and Moore (1997) for models in a similar spirit. Thus, we consider secured lending only. In Eisfeldt and Rampini (2005b) we consider the choice between secured lending and leasing (or renting) capital.

and

$$Rb \leq \theta p_u k(1-\delta). \tag{4}$$

Equations (1-2) are the budget constraints for time 0 and 1, with associated multipliers μ_0 and μ_1, respectively. The constraint (3) requires non-negativity of investment. Constraint (4) is the borrowing constraint which restricts borrowing to a fraction θ of the resale value of capital (in present value terms). Consumption will lie in the interior of $\mathbb{R}^2_+$ since we have assumed that the utility function satisfies an Inada condition. The multipliers associated with the non-negativity constraints for used and new capital investment are λ_u and λ_n, respectively. The multiplier on the credit constraint is λ_b. When this constraint binds ($\lambda_b > 0$), we will say that the agent is credit constrained, and that the agent is more credit constrained the larger this multiplier is. Note that at most one of the non-negativity constraints on investment in new and used capital (equation (3)) will be binding, since $\lim_{k\to 0} f'(k) = +\infty$.

2.3 Stationary Equilibrium

An economy can be described by the agent's utility function and discount rate along with the technology parameters for the production function, depreciation, and the used capital maintenance cost, the collateralization rate, and the support and distribution over initial endowments of internal funds. Thus, an economy $\mathbb{E}$ is defined by $\mathbb{E} = \{u(\cdot), \beta, \alpha, \delta, m_u, \theta, \mathcal{E}, \pi(e)\}$.

Definition 1 *A stationary equilibrium for an economy $\mathbb{E}$ is a used capital price p_u and an allocation $\{c_0^*, c_1^*, i_n^*, i_u^*, b^*\}$ of consumptions $\{c_0^*(e), c_1^*(e)\}$, investments in new and used capital $\{i_n^*(e), i_u^*(e)\}$, and borrowing $\{b^*(e)\}$ for all $e \in \mathcal{E}$ such that the following conditions are satisfied:*

(i) *The allocation $\{c_0^*, c_1^*, i_n^*, i_u^*, b^*\}$ solves the problem of each agent in generation t, $\forall e \in \mathcal{E}, t$.*

(ii) *The price of used capital p_u is such that the market for used capital clears given p_u, i.e., the amount of used capital sold by generation t equals the amount of used capital bought by generation $t+1$, $\forall t$:*

$$\sum_{e\in\mathcal{E}} \pi(e) i_n^*(e)(1-\delta) + \sum_{e\in\mathcal{E}} \pi(e) i_u^*(e)(1-\delta) = \sum_{e\in\mathcal{E}} \pi(e) i_u^*(e).$$

The right hand side of the market clearing condition in the above definition is the aggregate amount of used capital bought by each generation. The left hand side is the aggregate amount of capital sold by each generation, which is the sum of the aggregate amount of investment in new capital net of depreciation and the aggregate amount of investment in used capital net of depreciation.

If used capital were not cheap in terms of its purchase price, i.e., if $p_u \geq 1$, then all agents would buy new capital only, since new capital does not involve maintenance costs. However, if used capital were too cheap, specifically if the purchase price of used capital plus the maintenance costs discounted at β were strictly less than the cost of buying new capital, i.e., if $p_u + \beta m_u < 1$, then all agents would buy used capital and there would be no investment in new capital. Thus, in equilibrium, $1 - \beta m_u \leq p_u < 1$. Stated formally:

Proposition 1 *The price of used capital satisfies* $1 - \beta m_u \leq p_u < 1$ *in equilibrium.*

The proofs of this proposition and all other formal statements are in the appendix unless noted otherwise. Notice that the discount factor for time 1 payoffs of an agent who is not credit constrained is β and the price of used capital in an economy without credit constraints would hence be $p_u + \beta m_u = 1$. The price of used capital simply equals the price of new capital minus the discounted maintenance costs. The more interesting case is the one in which $p_u + \beta m_u > 1$, which we will refer to as the case of an economy with *credit constrained pricing* since in this case used capital is not priced as if there were no credit constraints. We study the properties of economies with credit constrained pricing below. We also discuss the properties of economies with *unconstrained pricing*, i.e., economies where $p_u + \beta m_u = 1$, and conditions under which credit constrained pricing obtains, i.e., conditions such that $p_u + \beta m_u > 1$.

2.4 Characterization of an Economy with Credit Constrained Pricing

In this section we characterize the used and new capital investment decision and equilibrium in an economy with credit constrained pricing. In the next section we provide conditions for an economy to exhibit credit constrained pricing along with an analogous characterization of an economy with unconstrained pricing. We will see that the main property of the model, that credit constrained firms buy more used capital, will be robust in both types of economies.

We first characterize the solution to the agent's problem in an economy with credit constrained pricing, i.e., under the assumption that $p_u + \beta m_u > 1$. We show that in such an equilibrium, it is agents with few internal funds who invest in used capital. Indeed, agents with internal funds below a certain threshold $\bar{e}_u$ invest only in used capital. Agents with internal funds in an intermediate range, i.e., between $\bar{e}_u$ and $\bar{e}_n > \bar{e}_u$, invest in both new and used capital. Agents with internal funds above $\bar{e}_n$ invest in new capital only. Furthermore, the size of an agent's firm measured in units or value of capital is increasing in e. The size of an agent's firm is strictly increasing below $\bar{e}_u$, is constant between $\bar{e}_u$ and $\bar{e}_n$, and then strictly increasing again above $\bar{e}_n$ until internal funds reach $\bar{\bar{e}} > \bar{e}_n$. Agents with internal funds above $\bar{\bar{e}}$ are unconstrained and their level of investment, and hence the size of their firm, is constant and equal to the unconstrained optimal firm size. Thus, agents with few internal funds are credit constrained, start smaller firms, and invest in used capital.

First, note that in an economy with credit constrained pricing, any agent who invests a positive amount in used capital must be credit constrained, that is, the multiplier on that agent's credit constraint must be strictly positive. This is stated formally in the following proposition.

Proposition 2 *Suppose $p_u + \beta m_u > 1$. If $i_u(e) > 0$, then $\lambda_b(e) > 0$.*

Thus, one can observe how credit constrained an agent in this economy is through revealed preference in their choice between new and used capital.[14] This seems an interesting implication, since identifying credit constrained firms has remained a challenge in the corporate finance literature.[15]

Next, we characterize the solution to the agent's problem as a function of e, the endowment or internal funds of the agent. The characterization is summarized in the next proposition:

Proposition 3 *Suppose $p_u + \beta m_u > 1$. There exist three cutoff levels of internal funds $\bar{e}_u < \bar{e}_n < \bar{\bar{e}}$ and levels of capital $\bar{k}$ and $\bar{\bar{k}}$, where $\bar{k} < \bar{\bar{k}}$, such that the solution to the agent's problem satisfies:*

[14] See Attanasio, Goldberg, and Kyriazidou (2005) for a related study of the decision to borrow in the auto loan market as a function of loan price and maturity for constrained and unconstrained consumers.

[15] See for example, Fazzari, Hubbard, and Petersen (1988), Kaplan and Zingales (1997), Lamont, Polk, and Saá-Réquejo (2001), and Whited and Wu (2003).

(i) *For* $e \leq \bar{e}_u$*,* $i_u > 0$*,* $i_n = 0$*, and* $b = \beta\theta p_u i_u(1-\delta)$*. Moreover,* $\frac{di_u}{de} > 0$*.*

(ii) *For* $\bar{e}_u < e < \bar{e}_n$*,* $i_u > 0$*,* $i_n > 0$*, and* $b = \beta\theta p_u(i_u + i_n)(1-\delta)$*. Moreover,* $i_u + i_n = \bar{k}$*,* $\frac{di_u}{de} < 0$*, and* $\frac{di_n}{de} > 0$*.*

(iii) *For* $\bar{e}_n \leq e \leq \bar{\bar{e}}$*,* $i_n > 0$*,* $i_u = 0$*, and* $b = \beta\theta p_u i_n(1-\delta)$*. Moreover,* $\frac{di_n}{de} > 0$*.*

(iv) *For* $e > \bar{\bar{e}}$*,* $i_n > 0$*,* $i_u = 0$*, and* $b < \beta\theta p_u i_n(1-\delta)$*. Moreover,* $i_n = \bar{\bar{k}}$*.*

Given the price of used capital p_u, the levels of capital $\bar{k}$ and $\bar{\bar{k}}$ and the cutoff level of internal funds $\bar{\bar{e}}$ can be computed in closed form. The cutoff levels of internal funds $\bar{e}_u$ and $\bar{e}_n$ can also be computed in closed form for the case where preferences satisfy $u(c) = \frac{c^{1-\gamma}}{1-\gamma}$. The closed form expressions are provided in the proof.

To understand this characterization in terms of total investment, notice that agents in this economy effectively have three ways to carry funds from time 0 to time 1. First, they can invest in the concave production technology. Second, they can save at a rate of return $R = \beta^{-1}$ which is constant. Third, by substituting new capital for used capital they can invest $1 - p_u$ at time 0 for a return of m_u, in terms of foregone maintenance costs, at time 1. The return on such a substitution is $m_u/(1-p_u) > \beta^{-1}$ and thus exceeds the rate of return on savings in an economy with credit constrained pricing. Hence, an agent first invests using the concave production technology until the marginal return reaches $m_u/(1-p_u)$. At that point the agent starts to substitute from used capital to new capital at a constant return of $m_u/(1-p_u)$ while keeping the capital stock constant at $\bar{k}$. Once he has fully substituted to new capital, he starts to increase the investment in the concave production technology again until the marginal return reaches β^{-1}. Thereafter, he saves at the constant return β^{-1} and keeps the capital stock at $\bar{\bar{k}}$.

The decision to invest in used and new capital depends on the agent's initial endowment of internal funds. Because of the credit constraint, the value of used vs. new capital is agent specific and depends on the level of internal funds. That is, the multiplier on the borrowing constraint drives a wedge between the valuations of agents with differing levels of internal funds. This is related to the result in the literature studying investment with financing constraints which shows that constrained firms make investment decisions which reflect the higher discount rate induced by binding credit constraints.[16] This can be seen by considering the first order conditions with

[16] See, for example, Whited (1992) and Bond and Meghir (1994).

respect to i_u and i_n which can be written as:

$$\mu_0 p_u + \mu_1 m_u - \lambda_u = \mu_1(f'(k) + p_u(1-\delta)) + \lambda_b \theta p_u(1-\delta), \quad (5)$$

$$\mu_0 - \lambda_n = \mu_1(f'(k) + p_u(1-\delta)) + \lambda_b \theta p_u(1-\delta). \quad (6)$$

The terms on the right hand side of equations (5) and (6) reflect the return on investing in used and new capital, respectively, in terms of output, resale value of capital, and shadow value of collateral. Since used and new capital are assumed to be perfect substitutes in production the returns are the same. The terms on the left hand side reflect the cost of investing in used capital $\mu_0 p_u + \mu_1 m_u$ and new capital μ_0, respectively. New and used capital can be valued for agents in each of the three endowment regions using the appropriate marginal rates of substitution. Since agents with internal funds between $\bar{e}_u$ and $\bar{e}_n$ invest in both new and used capital, the multipliers λ_u and λ_n are both zero and hence the shadow price of used capital for these agents satisfies:

$$p_u + \left[\beta \frac{u'(c_1(e))}{u'(c_0(e))}\right] m_u = 1, \quad (7)$$

where we have used the fact that $\mu_0(e) = u'(c_0(e))$ and $\mu_1(e) = \beta u'(c_1(e))$. This means that from the vantage point of an agent in this intermediate range, the shadow price of used capital equals the shadow price of new capital. Notice that the shadow price (or user cost) of used capital is agent specific and depends on the agent's endowment.

Agents with internal funds less than $\bar{e}_u$ however invest in used capital only and in this range $\lambda_n > 0$. Thus, from their vantage point used capital is relatively cheap, i.e., the shadow price of used capital satisfies:

$$p_u + \left[\beta \frac{u'(c_1(e))}{u'(c_0(e))}\right] m_u < 1. \quad (8)$$

Finally, for agents who invest in new capital only, i.e., agents with internal funds exceeding $\bar{e}_n$, $\lambda_u > 0$ and thus these agents consider new capital relatively cheaper than used capital:

$$p_u + \left[\beta \frac{u'(c_1(e))}{u'(c_0(e))}\right] m_u > 1. \quad (9)$$

New and used capital can also be valued for agents in each of the three endowment regions using the appropriate marginal rates of transformation.[17] This also shows

[17] Marginal rates of transformation have also been used to value assets in the production based asset pricing literature following Cochrane (1991, 1996), including Restoy and Rockinger (1994) and Gomes, Yaron, and Zhang (2003).

that with concave production technologies, even risk neutral agents would pay a premium for used capital if they were credit constrained and thus entrepreneurial risk aversion is not essential for our results. For agents with endowments between $\bar{e}_u$ and $\bar{e}_n$ we have:

$$p_u + \left[\frac{p_u(1-\beta\theta(1-\delta))}{f'(k(e)) + p_u(1-\delta)(1-\theta) - m_u}\right] m_u = p_u + \left[\frac{1-\beta\theta p_u(1-\delta)}{f'(k(e)) + p_u(1-\delta)(1-\theta)}\right] m_u = 1.$$

These agents invest in both new and used capital, hence the shadow price of a unit of used capital must equal the shadow price of a unit of new capital evaluated at the marginal rate of transformation implied by the level of capital chosen by agents with endowments in this region. Notice that these are the marginal rates of transformation for internal funds. For example, an extra unit of used capital costs p_u, but allows extra borrowing of $\beta\theta p_u(1-\delta)$, and thus costs $p_u(1-\beta\theta(1-\delta))$ in internal funds. The return on used capital is $f'(k)$ in terms of output, $p_u(1-\delta)(1-\theta)$ in terms of resale value net of loan repayment, and requires a maintenance payment of m_u, thus $f'(k) + p_u(1-\delta)(1-\theta) - m_u$ overall. The marginal rate of transformation for new capital has a similar interpretation. Recall that the optimal choice for capital (the sum of new and used capital investment) is increasing in initial endowment. For agents with internal funds less than $\bar{e}_u$ we have:

$$p_u + \left[\frac{p_u(1-\beta\theta(1-\delta))}{f'(k(e)) + p_u(1-\delta)(1-\theta) - m_u}\right] m_u < 1.$$

Thus, used capital is cheaper than new capital valued at the marginal rate of transformation for the most constrained agents. By investing in used capital, constrained agents can operate larger firms. Finally, for agents with internal funds exceeding $\bar{e}_n$ we have:

$$p_u + \left[\frac{1-\beta\theta p_u(1-\delta)}{f'(k(e)) + p_u(1-\delta)(1-\theta)}\right] m_u > 1,$$

which means that used capital is more expensive than new capital when valued by these unconstrained agents.

Two implications of the equilibrium pricing of used capital in an economy with credit constrained pricing are notable here. First, used capital is made expensive to unconstrained investors by the fact that it provides a convenience yield to constrained investors by relaxing their credit constraints and this makes these agents willing to pay more for used capital. Second, the premium at which used capital trades means that unconstrained agents invest more in equilibrium because they can sell capital at a premium in the used capital market. Of course, this is also true for used capital investment, however in this case the premium affects both the purchase and selling price.

2.5 Conditions for Credit Constrained Pricing

In order to provide conditions for credit constrained pricing, we will first briefly consider the properties of an economy with unconstrained pricing. The characterization is quite similar to the one in an economy with credit constrained pricing. In particular, agents with few internal funds are credit constrained, buy only used capital, and start smaller firms. There are two main differences, however. The first difference is that investment in new capital is not uniquely determined for all agents. The minimum amount an agent invests in used capital, however, is uniquely determined and has the same properties as before. The minimum investment in used capital is 100% of investment for agents with internal funds below some threshold $\bar{e}_u$, then decreases over an interval of intermediate values of internal funds between $\bar{e}_u$ and $\bar{e}_n$, and is zero above $\bar{e}_n$. The second difference is that with unconstrained pricing an agent's total investment is strictly increasing below $\bar{e}_u$ only. The third region of Proposition 3 thus collapses, i.e., $\bar{e}_n = \bar{\bar{e}}$ using the notation of that proposition.[18] The characterization of the agent's problem is summarized in Proposition 4 below.

To see that investment in new capital is not uniquely determined consider the following argument: Any agent who is willing to invest a positive amount in new capital would be indifferent between doing so and raising the investment in used capital by a small amount while reducing his investment in new capital by the same small amount and reducing borrowing (or increasing savings) by the difference. Specifically, increasing i_u by Δ and reducing i_n by the same amount frees up $(1 - p_u)\Delta$ units of consumption at date 0. Reducing borrowing (or increasing savings) b by that amount leaves consumption at date 0 unchanged, and pays off $R(1 - p_u)\Delta$ at date 1. Maintenance costs at date 1 increase by $m_u\Delta$, but the reduction in borrowing (or increase in savings) exactly covers that. Thus consumption at date 1 is not affected either.

We denote the minimum investment in used capital, which is determined uniquely given the agent's internal funds e, by i_u^{min} and the corresponding maximum invest-

[18] The reason is that in an equilibrium with unconstrained pricing the return on saving, $R = \beta^{-1}$, equals the return on substituting new capital for used capital, $m_u/(1 - p_u) = \beta^{-1}$.

ment in new capital by i_n^{max}. Similarly, we denote the implied maximum borrowing by b^{max}. The solution can then be characterized as follows:

Proposition 4 *Suppose $p_u + \beta m_u = 1$. There exist two cutoff levels of internal funds $\bar{e}_u < \bar{e}_n$ and a level of capital $\bar{k}$ such that the solution to the agent's problem satisfies:*

(i) *For $e \leq \bar{e}_u$, $i_u > 0$, $i_n = 0$, and $b = \beta\theta p_u i_u(1-\delta)$. Moreover, $\frac{di_u}{de} > 0$.*

(ii) *For $\bar{e}_u < e < \bar{e}_n$, $i_u^{min} > 0$, $i_n^{max} > 0$, and $b^{max} = \beta\theta p_u(i_u + i_n)(1-\delta)$. Moreover, $i_u + i_n = \bar{k}$, $\frac{di_u^{min}}{de} < 0$, and $\frac{di_n^{max}}{de} > 0$.*

(iii) *For $e \geq \bar{e}_n$, $i_n^{max} > 0$, $i_u^{min} = 0$, and, for $e > \bar{e}_n$, $b^{max} < \beta\theta p_u(i_u + i_n)(1-\delta)$. Moreover, $i_u + i_n = \bar{k}$ and $\frac{di_n^{max}}{de} = 0$.*

Closed form solutions for the two cutoff levels of internal funds $\bar{e}_u$ and $\bar{e}_n$ as well as the level of capital $\bar{k}$ are provided in the proof.

We can now determine the conditions for the economy to have unconstrained pricing versus credit constrained pricing. The maximum aggregate amount of new capital sold after one period given unconstrained pricing, i.e., $p_u + \beta m_u = 1$, is

$$\sum_{e \in \mathcal{E}} \pi(e) i_n^{max}(e)(1-\delta)$$

while the minimum aggregate net amount of used capital investment given unconstrained pricing is

$$\sum_{e \in \mathcal{E}} \pi(e) i_u^{min}(e)\delta.$$

Notice that both these expressions involve only parameters since $p_u = 1 - \beta m_u$ with unconstrained pricing. From Definition 1, market clearing requires that

$$\sum_{e \in \mathcal{E}} \pi(e) i_n^*(e)(1-\delta) = \sum_{e \in \mathcal{E}} \pi(e) i_u^*(e)\delta.$$

Thus, if

$$\sum_{e \in \mathcal{E}} \pi(e) i_n^{max}(e)(1-\delta) \geq \sum_{e \in \mathcal{E}} \pi(e) i_u^{min}(e)\delta,$$

then unconstrained agents are willing to invest more than enough in new capital to satisfy the net demand for used capital. This means that the marginal used capital investor is an unconstrained agent and hence we have unconstrained pricing in equilibrium. However, if the converse is true, then some constrained agents need to invest in new capital and hence the marginal agent pricing used capital is constrained. Hence, credit constrained pricing obtains in equilibrium under the following condition:

Condition 1 $\sum_{e \in \mathcal{E}} \pi(e) i_n^{max}(e)(1-\delta) < \sum_{e \in \mathcal{E}} \pi(e) i_u^{min}(e)\delta.$

2.6 Numerical Example

To illustrate and compare economies with credit constrained and unconstrained pricing, we present two example economies. In particular, we study the decision to invest in used vs. new capital as a function of agents' initial internal funds and the premium used capital trades at in the economy with credit constrained pricing. The only difference in primitives between the two economies is the distribution over endowments of internal funds. To construct an economy with credit constrained pricing, we know that Condition 1 must be satisfied. In our example economy with credit constrained pricing, the distribution over endowments is exponential on the state space, so that there are more agents with low endowments than high endowments, whereas endowments are distributed uniformly in the economy with unconstrained pricing. Thus, the internal funds distribution determines whether used capital trades at a premium and the magnitude of this premium. This has the interesting implication that, in the cross section, used capital should trade at a higher premium in industries (or countries) with more firms with low levels of internal funds.

For preferences, we specify that $u(c) = \frac{c^{1-\gamma}}{1-\gamma}$. Table 1 presents the parameters which define the two example economies. We use the conventional values for the standard preference and technology parameters and choose values for the additional parameters, m_u and θ, and distributions of internal funds to illustrate the implications of the model.

We first discuss the results for the economy with credit constrained pricing. Used capital trades at a premium in this economy. Under unconstrained pricing, the price of used capital equals the price of new capital (one) minus βm_u, while in this economy $p_u > 1 - \beta m_u$ and the shadow price of used capital is $p_u + \beta m_u > 1$. The fact that agents with low endowments, who are credit constrained, can start larger firms by investing in used capital (that is, used capital relaxes credit constraints for these agents) means that used capital earns a convenience yield which raises the equilibrium price of used capital. The price of used capital in the two economies is presented in Table 2 along with the other equilibrium implications for the two economies.

Next, we describe the investment decisions by agents in the economy with credit constrained pricing. As stated in Proposition 3, there are three increasing cutoff levels for internal funds, defining four investment regions. Figure 1 presents the investment and savings decisions, along with the shadow price of used capital, and the multiplier on the borrowing constraint, in such an economy as a function of agents' initial endowments of internal funds. The top left panel plots new and used capital investment. For low endowment levels, below $\bar{e}_u$, agents invest only in used capital and investment is increasing in this range. At higher levels of internal funds, between $\bar{e}_u$ and $\bar{e}_n$, agents invest an increasing amount in new capital, and a decreasing amount in used capital. Total investment is constant at $\bar{k}$. Used capital investment reaches zero at $\bar{e}_n$ and agents with endowments greater than $\bar{e}_n$ invest only in new capital. Between $\bar{e}_n$ and $\bar{\bar{e}}$ investment in new capital increases until total investment reaches $\bar{\bar{k}}$ at $\bar{\bar{e}}$ and capital investment is constant thereafter. Agents in this region are unconstrained and begin to borrow less than their borrowing capacity. The top right panel of Figure 1 plots borrowing. Agents with internal funds below $\bar{\bar{e}}$ borrow up to their borrowing capacity and borrowing is increasing in this range. Above $\bar{\bar{e}}$, borrowing is decreasing and agents with lots of internal funds save positive amounts. The middle left panel plots the fraction of capital expenditures comprised by used capital, which decreases monotonically with internal funds. The bottom left panel describes why this is the case along with what motivates the investment decision described above, by plotting the shadow prices for used and new capital as a function of internal funds. The shadow price of new capital is one, and the shadow price of used capital, described in equations (7)-(9), is increasing with the level of internal funds. The shadow price of used capital is less than one for agents who invest only in used capital, equals one in the intermediate region where agents are indifferent between used and new capital, and exceeds one for agents who invest only in new capital and for agents who are unconstrained. Finally, the middle right panel of Figure 1 plots the multiplier on agents' borrowing constraints. This multiplier monotonically decreases with internal funds, and reaches zero for unconstrained agents, who borrow less than their borrowing capacity.

We turn now to the results of the economy with unconstrained pricing for comparison in which used capital sells for $1 - \beta m_u$. The other results are similar to those for the economy with credit constrained pricing, and are presented in the bottom panel of Table 2. However, as described in Proposition 4, investment in new capital and savings are only uniquely defined for agents with internal funds less than $\bar{e}_u$, who do not purchase any new capital. Agents with higher endowments are indifferent between appropriately combining reduced borrowing with used capital and investing in new capital at the margin. Also, total investment is increasing in initial internal funds only for agents who invest only in used capital. Still, as in the economy with credit constrained pricing, agents with low endowments invest exclusively in used capital, are constrained, and start smaller firms. Moreover, above $\bar{e}_u$ the minimum investment in used capital is monotonically decreasing in agents' endowment, and reaches zero at $\bar{e}_n$, where maximum borrowing no longer exhausts agents' borrowing capacity. Analogous to Figure 1 for the case with credit constrained pricing, Figure 2 presents the investment and borrowing decisions, along with the shadow price of used capital, and the multiplier on the borrowing constraint, in the economy with unconstrained pricing as a function of agents' initial endowment of internal funds. Notice that $\bar{e}_u$ is higher in the economy with unconstrained pricing than in the economy with credit constrained pricing so agents with higher endowment levels invest exclusively in used capital. This is because the price of used capital is not inflated by the effect of credit constraints. For the same reason, in the economy with unconstrained pricing unconstrained agents are willing to invest in both new and used capital, in contrast to the economy with credit constrained pricing. In fact, only unconstrained agents are willing to invest in both used and new capital. To see this, compare the top left and middle right panels of Figure 2, which plot investment and the multiplier on the borrowing constraint, respectively.

3 Evidence on Investment in New and Used Capital

Our model predicts that firms with less internal funds are credit constrained, invest more in used capital, and operate smaller firms. We first focus on the prediction that the fraction of investment comprised by used capital and firm size are negatively related and find evidence that used to total capital expenditures are strongly decreasing with firm size. The stylized fact that small firms invest much more in used capital is very robust and, to the best of our knowledge, new. We acknowledge, however, that while financially constrained firms are likely to operate at a smaller scale than would be optimal in the absence of financial constraints, size is also affected by purely technological factors. Thus, we provide direct evidence on the link between the fraction of investment in used capital and measures of financial constraints. We find that firms which seem more financially constrained invest more in used capital. Finally, we study the robustness of the financial measures of credit constraints to alternative explanations for the relationship between size and investment in used capital. We add controls consistent with the following three alternative explanations: First, there is likely to be a smaller difference between the purchase and resale price of used capital, and this might make it attractive to firms which value its reversibility.[19] Second, firms facing higher tax rates might favor new capital. Third, new capital might be complementary to other factors of production, such as a skilled workforce.[20] We find that the relationship between used to total capital expenditures and measures of financial constraints is largely unaffected by adding these controls.

In addition to our evidence about systematic variation in used capital expenditures at the firm level, it is also interesting to note that in the aggregate small firms are important in used capital markets. Indeed, about thirty percent of aggregate used capital expenditures is done by businesses with no employees, while these businesses contribute only about eight percent of aggregate total capital expenditures.[21] This means that understanding the investment behavior of small, credit constrained firms is likely important to understanding the behavior of used capital markets. Furthermore, since small, credit constrained firms have been argued to be particularly sensitive to aggregate fluctuations and central to understanding business cycles and growth, the market for used capital may then be important for understanding this connection.

3.1 Data

We use two main data sources for estimates of used capital expenditures, the Vehicle Inventory and Use Survey (VIUS) and the Annual Capital Expenditure Survey (ACES), both by the U.S. Census Bureau.

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[19]The wedge between the purchase and resale price of used vs. new capital is smaller in our model, where both new and used capital are sold for p_u after use in production, however there is no variation in the value of reversibility. See Abel and Eberly (1994) for the effects of partial reversibility on investment decisions. See Ramey and Shapiro (1998) for a model where markets for used capital are thin due to capital specificity and a search and matching friction.

[20]See Oi (1983) for a similar argument and some evidence, and Jovanovic (1998) for a model of vintage capital where skilled labor and the newest vintage are complements.

[21]See the 2002 Annual Capital Expenditures Survey report.

The Vehicle Inventory and Use Survey (VIUS) is a survey of the truck population in the U.S. and provides information about the physical and operational characteristics of trucks in the U.S. We use the publicly available micro data file of the 1997 VIUS.[22] The observation unit in this survey is a truck. The survey asks whether a truck was purchased new or used, what the size is of the fleet that the truck is a part of, and whether the truck was used for business use. We use data on trucks dedicated to business use only.

The Annual Capital Expenditure Survey (ACES) is a comprehensive survey of capital investment by nonfarm businesses covering all sectors. We use both data from the public ACES reports and confidential ACES micro data.[23] We are among the first researchers to use the confidential ACES micro data. The 2002 ACES, for example, is based on a sample of approximately 46,000 companies with employees and approximately 15,000 companies without employees representing a sample frame of approximately 5.6 million companies with employees and 20.3 million companies without employees. The survey asks firms to report their capital expenditures on new capital and used capital, where used capital is defined as "buildings and other structures which have been previously owned and occupied, machinery and second-hand equipment, and other used depreciable assets." The cost of land is excluded. To get a sense of the characteristics of capital expenditures on used capital we report the main types of used structures and equipment expenditures in Table 4 based on the 1998 ACES report. Table 5 shows the fraction of used capital expenditures (as percent of total capital expenditures) across industries and shows that there is considerable cross industry variation in the importance of used capital.

To study the relationship between used capital expenditures and size using the ACES micro data, we exclude firms with zero assets and only use data for firms with employees since ACES does not contain information about assets of firms without employees.

To study the relationship between used capital expenditures and financial variables we merge the ACES data with data from Compustat using a Census-Compustat bridge file. We restrict the data to the 1998 ACES since that year is a detailed survey year and the data quality is likely higher.[24] Moreover, the annual panel rotation

[22]The VIUS reports and additional information about the VIUS are available at http://www.census.gov/econ/www/viusmain.html.

[23]The ACES reports and additional information about the ACES are available at http://www.census.gov/csd/ace/.

[24]The Census Bureau collected more detailed information on capital expenditures in 1998 (and

limits the extent to which the panel dimension of the data can be exploited.

3.2 Evidence on Used Capital Expenditures and Size

We first provide evidence on the choice between new and used trucks as a function of the size of the fleet using data from the 1997 VIUS. Table 3 presents data for trucks dedicated to business use. Overall, about 50% of trucks were purchased used. This fraction decreases monotonically with fleet size. For example, businesses with fleets of 10 to 24 purchased about 38% of their trucks used, whereas businesses with fleets of 100 to 499 vehicles purchased only about 24% of their trucks used. Figure 3 displays this information graphically, and for different body types. Businesses with the smallest fleets buy at least 40% of trucks of all body types used, while businesses with the largest fleets buy no more than 37% of trucks of any body type used.

Next we provide evidence on the composition of capital expenditures on new vs. used capital for firms of different sizes. Table 6 presents the composition of capital expenditures on new and used structures and equipment for companies with and without employees using data from the publicly available ACES reports. Clearly, small companies (i.e., companies without employees) invest a larger fraction of their capital expenditures in used capital. The fraction of capital expenditures comprised by used capital for small firms is about five times the fraction for large firms. This pattern is robust across years and is similar for structures and equipment. Moreover, the composition of capital expenditures in terms of structures vs. equipment is similar for firms with and without employees, which suggests that firms with and without employees operate similar technologies and the main difference between them is whether the capital is purchased new or used.

Table 7 presents the average ratio of used capital expenditures to total capital expenditures across firm size deciles using ACES micro data from 1993 to 2002. We measure firm size using assets at the beginning of the year and report data for overall capital expenditures, and for structures and equipment separately.[25] For overall capital expenditures, expenditures on structures, and expenditures on equipment, the fraction of expenditures comprised by used capital decreases monotonically in size. Again, this supports the idea that small firms have a similar composition of building and equipment capital to large firms, and thus may operate similar technologies at a

again in 2003, but the data from the 2003 survey is not yet available).

[25] Details of the data construction are given in Table 7.

smaller scale. For overall capital expenditures, used capital comprises 28% of capital expenditures for firms in the lowest asset decile (with assets below $0.10 million) and 10% for firms in the highest asset decile (with assets exceeding $186.55 million) and this fraction decreases monotonically across asset deciles. Figure 4 clearly illustrates the relationship between size and used capital expenditures for capital overall, and equipment and structures separately. Thus, we conclude that small firms invest more in used capital than large firms.

The relationship between size and used capital expenditures is robust and can be documented for a large universe of firms, including non-public firms for which financial data is unavailable. The idea that small firms are more likely to be credit constrained is also supported by studies of the effects of credit constraints on investment. For example, Whited and Wu (2003) report that for both their index of credit constraints, as well as the Kaplan and Zingales (1997) index used by Lamont, Polk, and Saá-Réquejo (2001), average firm assets decrease monotonically with the degree of financial constraints. Moreover, classic models of borrowing constraints link internal funds to the degree of financial constraints.[26] Likewise, in our model small firms are constrained and have a larger multiplier on their borrowing constraint. The effect of credit constraints is manifested in the composition of investment in terms of new and used capital and in firm size.

3.3 Evidence on Used Capital Expenditures and Financial Variables

This section provides direct evidence on the link between the fraction of capital expenditures on used capital and measures of financial constraints. We use the ACES micro data for the fraction of capital expenditures on used capital and data from Compustat for the financial variables. We report results for overall capital expenditures, as well as structures and equipment separately to check that the results for overall capital expenditures are not due to variation in the composition of capital expenditures by type.

Table 9 reports the results of cross-sectional regressions using data on overall capital expenditures for 1998. We provide estimates from regressions of the fraction of capital expenditures on used capital on financial variables, an intercept, and industry dummies. We use the financial variables shown by Kaplan and Zingales (1997) to have

[26] See Townsend (1979), Gale and Hellwig (1985), and Bernanke and Gertler (1989).

the expected relationship with the degree to which the firm is financially constrained. They used qualitative information in SEC filings to rank firms' financial constraints, and showed that firms which indicated high levels of constraints were smaller, paid lower dividends relative to assets, had higher debt to assets, lower cash flow to assets, higher Tobin's q, and lower cash to assets. We first provide regressions of used to total capital expenditures on each of these financial variables controlling for size and industry dummies, and then on all variables simultaneously, also controlling for industry at the three digit level. The details of the variables used and descriptive statistics are in Table 8.

Overall, the estimates suggest that there is a significant relationship with the predicted sign between the fraction of capital expenditures on used capital and the financial variables. We first examine the relationship between used to total capital expenditures and each of the financial variables controlling for size and industry dummies. All variables except cash flow to assets have the predicted relationship with used to total capital expenditures when controlling for size. Moreover, all variables except this cash flow measure and Tobin's q are significant at the 5% level.[27] These regressions show that the fraction of capital expenditures on used capital is significantly higher for smaller firms, for firms which pay lower dividends (relative to assets), for firms with more long-term debt (relative to assets), and for firms with less cash (relative to assets). Thus, the financial variables contain additional information relative to size alone. When all variables are included simultaneously, the sign on all financial measures of constraints remains unchanged. The sign and significance of size is unchanged. Long term debt to assets and Tobin's q gain in significance, while the significance of dividends to assets and cash to assets declines. This is to be expected since these variables are likely to capture some of the same information. Moreover, all our significant estimates have the same sign as those found by Kaplan and Zingales (1997) in their estimation of an ordered logit which relates a qualitative measure of financial constraints to these financial variables. The estimates are also economically important since a one standard deviation change in any of the significant independent variables changes the fraction of used capital expenditures by 1-2%, which is considerable given the mean of 12%.

Notice that when we use the merged ACES-Compustat data we use data for relatively large firms since Compustat firms are publicly held. In terms of the asset

[27] See Erickson and Whited (2005) and papers cited therein for a detailed description of the effects of measurement error in Tobin's q.

deciles from Table 7 we are hence likely only using data for the top few deciles where there is relatively little variation in the average fraction of capital expenditures on used capital (which varies between about 13% and 10% in the top 4 deciles for example). Indeed, the mean of the fraction of capital expenditures on used capital is 12% in the merged data (see Table 8) which equals the value in the eighth decile. Moreover, more than 50% of the observations in the merged sample must be in the top decile, since the median value of assets is over $650 million (which is considerably above the bottom cutoff of the top decile). Nevertheless, we find a significant relationship between used capital expenditures and measures of financial constraints here. This suggests the following *tip of the iceberg* hypothesis: To the extent that we can extrapolate from our results using size as the proxy for financial constraints, smaller firms appear considerably financially constrained since the fraction of capital expenditures on used capital is much higher (up to 28%) for smaller firms for which we do not have other measures of financial constraints.

To check the robustness of the relationship between used to total capital expenditures and measures of financial constraints, we also include in Table 9 results including controls suggested by three alternative explanations. First, we investigate whether firms which might value reversibility invest relatively more in used capital by including firm age and the standard deviation of sales growth over the last five years. We find neither variable to be significant when size and the measures of financial constraints are included in the regression. Moreover, the coefficients on size and long term debt are unaffected by these additional controls. The main effect on the coefficients on the financial variables is that q loses significance. Next, we investigate whether firms which face higher tax rates invest relatively less in used capital. We use two alternative tax rates, an average tax rate and a before financing marginal tax rate.[28] Neither rate has a significant relationship to used to total capital expenditures and they have opposite signs when included separately. Moreover, q gains significance with the inclusion of either variable. We do not think there is a clear cut expected sign for the tax rate, since both depreciation (which might be higher for new capital) and maintenance (which we argue is higher for used capital) are expenses which can be deducted from taxable income. Finally, we include variables intended to capture the potential complementarity between skilled labor and/or specialized assets in place, and new capital. We include in our regression the ratio of property,

[28]This variable was provided to us by John Graham. See, for example, Graham, Lemmon, and Schallheim (1998) for a detailed description.

plant and equipment to employees to capture the capital labor ratio with the idea that firms with skilled labor have higher capital to labor ratios. We include the ratio of R&D to sales to capture the idea that firms with specialized assets in place are likely to spend more on R&D. We also add the ratio of sales to employees to capture the idea that firms with more skilled labor should have more sales per employee. We find that none of these variables are significant except for sales to employees, which has a negative coefficient which is significant at the 10% level. Although this is consistent with a complementarity between new capital and skilled labor, it is also consistent with the idea that constrained firms might have lower sales to employees. Finally, we include all controls in the last regression in Table 9. Size is significantly negative at the 1% level in this regression. Although size may be affected by technological considerations, we argue that, when controlling for the technological factors described above, the remaining explanatory power of size may reflect the effect of financial constraints.

Tables 10 and 11 replicate the analysis for structures and equipment expenditures separately. We find similar results for both measures. In particular, for both structures and equipment, size and long term debt to assets have the most significant relationship with used to total capital expenditures of all the financial measures. For structures, the coefficient on taxes is significantly negative which indicates that firms with higher tax rates invest relatively more in new structures. Also for structures, the R&D to sales ratio has a significantly positive sign which indicates that firms with higher R&D invest relatively more in used structures. This is evidence against complementarity between specialized capital and investment in new structures. However, for equipment, when all variables are included in the regression, the coefficient on PP&E to employees becomes significantly positive which is consistent with skilled labor and new capital being complements. Importantly, the measures of financial constraints appear relatively robust to the non-financial controls.

3.4 Evidence for Consumers

We focus on the investment decision by firms, however, one can apply the same logic to individual consumers and households to understand used durable goods markets. Credit constrained households may buy used capital because the higher maintenance cost allow them to partially pay for it later on. Indeed, Aizcorbe and Starr-McCluer (1997) report evidence that households with lower income and lower financial assets buy a larger fraction of cars used.

Aizcorbe and Starr-McCluer (1997) use data from the Survey of Consumer Finances and the Consumer Expenditure Interview Survey for 1992 and find that households with income below $10,000 (1992 dollars) buy 64.3% and 61.2% of cars used (in the Survey of Consumer Finances and the Consumer Expenditure Interview Survey, respectively), while households with income of $100,000 or more buy 34.0% and 35.9% used. Similarly, households with financial assets below $500 (1992 dollars) buy 77.3% and 79.9% used, while households with financial assets of $10,000 or more buy 39.3% and 39.6% used.

Moreover, they report that households with lower income and lower financial assets also tend to buy used cars which are older. The data from the Survey of Consumer Finances and the Consumer Expenditure Interview Survey, respectively, for the average age of used vehicles at the time of acquisition are 7.9 and 8.0 years for households with financial assets below $500 (1992 dollars) and 5.2 and 6.4 years for households with financial assets of $10,000 or more. By income, the Survey of Consumer Finances suggest ages of 7.8 years for households with income below $10,000 (1992 dollars) and 5.1 years for households with income of $100,000 or more, while the Consumer Expenditure Interview Survey in contrast suggest 6.8 years and 7.7 years, respectively.

This would be consistent with an extension of our model where maintenance costs continue to increase with the age of the capital good, and hence a larger fraction of the user cost of older capital would occur in terms of maintenance rather than up front investment, which makes it attractive to credit constrained households.

4 Conclusions

This paper develops a model of the decision to invest in new vs. used capital when used capital has a lower purchase price, but requires maintenance payments later on. We find that used capital is valuable to credit constrained agents because it relaxes borrowing constraints. Used capital allows constrained agents to operate larger scale firms by deferring some of the capital costs. This is interesting because it implies that firms' credit constraints can be measured by the composition of their capital expenditures. We find that agents with low levels of internal funds invest more in used capital, are credit constrained, and operate smaller scale firms. Credit constraints imply that discount factors are firm specific and used capital can thus seem cheap from the vantage point of a constrained firm while unconstrained firms consider it expensive.

We present evidence that used capital indeed comprises a much larger fraction of capital expenditures for small firms who are likely to face binding credit constraints. Moreover, the fraction of capital expenditures on used capital is significantly related to measures of financial constraints, with more constrained firms using a larger fraction of used capital. We document these facts for capital overall as well as for structures and equipment separately. The fact that small and credit constrained firms invest in relatively more used capital is important for understanding used capital markets. Our model implies that the fraction of credit constrained firms affects the premium at which used capital trades. Understanding who buys used capital, and why, is also important for studying capital reallocation and aggregate investment dynamics.

While we focus on the investment decision by firms, we argue that one can apply the same logic to individual consumers and households to understand used durable goods markets. More generally, our results shed light on the choice between capital vintages and consumer durables of different quality, which are typically motivated by exogenous variation in preferences for vintages or quality.

Appendix

Proof of Proposition 1. Notice that the objective of the agent's problem is concave and the constraint set convex and hence the first order conditions are necessary and sufficient. The first order conditions with respect to i_u and i_n are

$$\mu_0 p_u = \mu_1(\alpha k^{\alpha-1} + p_u(1-\delta) - m_u) + \lambda_u + \lambda_b \theta p_u(1-\delta) \quad (10)$$

$$\mu_0 = \mu_1(\alpha k^{\alpha-1} + p_u(1-\delta)) + \lambda_n + \lambda_b \theta p_u(1-\delta) \quad (11)$$

and with respect to b is $\mu_0 = \mu_1\beta^{-1} + \lambda_b\beta^{-1}$, where μ_t is the multiplier on date t consumption, λ_u and λ_n are the multipliers on the non-negativity constraints for i_u and i_n, respectively, and λ_b is the multiplier on the borrowing constraint. Subtracting (10) from (11) gives

$$\mu_0(1-p_u) = \mu_1 m_u + \lambda_n - \lambda_u. \quad (12)$$

Thus, if $p_u \geq 1$, then $\lambda_u > 0$ (the strict inequality follows from the fact that $\mu_1 > 0$) and hence $i_u = 0$ for all $e \in \mathcal{E}$, which is impossible in equilibrium. If $p_u < 1 - \beta m_u$, then using this inequality and (12), we have

$$\mu_0 \beta m_u < \mu_0(1-p_u) = \mu_1 m_u + \lambda_n - \lambda_u$$

and substituting for μ_0 using the first order condition with respect to b we get $\lambda_b m_u < \lambda_n - \lambda_u$. Thus, $\lambda_n > 0$ and hence $i_n = 0$ for all $e \in \mathcal{E}$ which is again impossible in equilibrium. □

Proof of Proposition 2. Since $i_u > 0$, $\lambda_u = 0$, where we have suppressed the dependence on e to simplify notation. Equation (12) together with $p_u + \beta m_u > 1$ and $\mu_0 = \mu_1\beta^{-1} + \lambda_b\beta^{-1}$ then imply that

$$\mu_1 m_u + \lambda_n = \mu_0(1-p_u) < \mu_0\beta m_u = \mu_1 m_u + \lambda_b m_u$$

or $\lambda_n < \lambda_b m_u$ which implies $\lambda_b > 0$. □

Proof of Proposition 3. Note that the objective is continuous and strictly concave and that the constraint set is convex and continuous. Thus, by the theorem of the maximum (see, e.g., Stokey, Lucas, and Prescott (1989)), the maximizing choices are continuous in e.

First, suppose $i_u > 0$ where we suppress the dependence on e for simplicity. Then, by Proposition 2, $\lambda_b > 0$, i.e., $b = \beta\theta p_u(i_u + i_n)(1-\delta)$. Consider the case where

$i_n = 0$. Then the first order condition with respect to i_u, equation (10), can be written as

$$u'(e - p_u i_u(1-\beta\theta(1-\delta)))p_u(1-\beta\theta(1-\delta)) = \beta u'(i_u^{\alpha} + p_u i_u(1-\delta)(1-\theta) - m_u i_u) \times (\alpha i_u^{\alpha-1} + p_u(1-\delta)(1-\theta) - m_u) \quad (13)$$

where we substituted for λ_b using $\mu_0 = \mu_1\beta^{-1} + \lambda_b\beta^{-1}$. By totally differentiating we get

$$\frac{di_u}{de} = \frac{u''(c_0)p_u(1-\beta\theta(1-\delta))}{u''(c_0)(p_u - \beta\theta p_u(1-\delta))^2 + \beta u''(c_1)(f'(k) + p_u(1-\delta)(1-\theta) - m_u)^2 + \beta u'(c_1)f''(k)} > 0. \quad (14)$$

Next, consider the case where both $i_u > 0$ and $i_n > 0$, such that the first order conditions with respect to i_u and i_n are, again substituting for λ_b,

$$\mu_0 p_u(1-\beta\theta(1-\delta)) = \mu_1(\alpha k^{\alpha-1} + p_u(1-\delta)(1-\theta) - m_u) \quad (15)$$

$$\mu_0(1-\beta\theta p_u(1-\delta)) = \mu_1(\alpha k^{\alpha-1} + p_u(1-\delta)(1-\theta)) \quad (16)$$

Dividing equation (15) by equation(16) implies

$$\frac{p_u - \beta\theta p_u(1-\delta)}{1-\beta\theta p_u(1-\delta)} = 1 - \frac{m_u}{\alpha k^{\alpha-1} + p_u(1-\delta)(1-\theta)} \quad (17)$$

and thus k is uniquely determined and constant in this range and equals $\bar{k} = \left(\alpha^{-1}(\frac{m_u}{1-p_u}(1-\beta\theta p_u(1-\delta)) - p_u(1-\delta)(1-\theta))\right)^{\frac{1}{\alpha-1}}$. Totally differentiating (16) implies that

$$\frac{d\mu_0}{de}(1-\beta\theta p_u(1-\delta)) = \frac{d\mu_1}{de}(\alpha\bar{k}^{\alpha-1} + p_u(1-\delta)(1-\theta)),$$

and thus $\frac{d\mu_0}{de}$ and $\frac{d\mu_1}{de}$ have the same sign. Since it is not possible that the agent's consumption at both dates decreases in e, the sign must be negative, which in turn implies that $\frac{dc_1}{de} > 0$. Totally differentiating the time 1 budget constraint gives $\frac{dc_1}{de} = -m_u\frac{di_u}{de}$ and thus $\frac{di_u}{de} < 0$ and $\frac{di_n}{de} > 0$.

At the upper boundary of this region, the capital $\bar{k}$ is entirely made up by new capital. Equation (16) can then be written as

$$u'(e - \bar{k}(1-\beta\theta p_u(1-\delta)))(1-\beta\theta p_u(1-\delta)) = \beta u'(\bar{k}^{\alpha} + p_u\bar{k}(1-\delta)(1-\theta)) \times (\alpha\bar{k}^{\alpha-1} + p_u(1-\delta)(1-\theta)) \quad (18)$$

which implicitly defines the upper bound on internal funds $\bar{e}_n$. If $u(c) = \frac{c^{1-\gamma}}{1-\gamma}$ and using equation (17), we can solve for $\bar{e}_n$: $\bar{e}_n = \bar{k}(1-\beta\theta p_u(1-\delta)) + (\bar{k}^\alpha + p_u\bar{k}(1-\delta)(1-\theta))\left(\frac{\beta m_u}{1-p_u}\right)^{-\frac{1}{\gamma}}$. At the lower boundary of the region, the agent only invest in used capital and hence

$$
\begin{aligned}
u'(e - p_u\bar{k}(1-\beta\theta(1-\delta))) &= \beta u'(\bar{k}^\alpha + p_u\bar{k}(1-\delta)(1-\theta) - m_u\bar{k}) \times \\
&\quad (\alpha\bar{k}^{\alpha-1} + p_u(1-\delta)(1-\theta)) \qquad (19)
\end{aligned}
$$

which implicitly defines the lower bound on internal funds $\bar{e}_u$. Proceeding as above, we obtain $\bar{e}_u = p_u\bar{k}(1-\beta\theta(1-\delta)) + (\bar{k}^\alpha + p_u\bar{k}(1-\delta)(1-\theta) - m_u\bar{k})\left(\frac{\beta m_u}{1-p_u}\right)^{-\frac{1}{\gamma}}$. Comparing (18) and (19) implies $u'(\bar{e}_u - p_u\bar{k}(1-\beta\theta(1-\delta))) > u'(\bar{e}_n - \bar{k}(1-\beta\theta p_u(1-\delta)))$ or $\bar{e}_u - p_u\bar{k}(1-\beta\theta(1-\delta)) < \bar{e}_n - \bar{k}(1-\beta\theta p_u(1-\delta))$ and thus $\bar{e}_u < \bar{e}_n$.

Finally, suppose $i_n > 0$ and $i_u = 0$. Consider the case where $\lambda_b > 0$ and hence $b = \beta\theta p_u i_n(1-\delta)$. Then equation (11), again substituting for λ_b, can be written as

$$
\begin{aligned}
u'(e - i_n(1-\beta\theta p_u(1-\delta)))(1-\beta\theta p_u(1-\delta)) &= \beta u'(i_n^\alpha + p_u i_n(1-\delta)(1-\theta)) \times \\
&\quad (\alpha i_n^{\alpha-1} + p_u(1-\delta)(1-\theta)).
\end{aligned}
$$

By totally differentiating we get

$$
\begin{aligned}
\frac{di_n}{de} &= \frac{u''(c_0)(1-\beta\theta p_u(1-\delta))}{u''(c_0)(1-\beta\theta p_u(1-\delta))^2 + \beta u''(c_1)(f'(k) + p_u(1-\delta)(1-\theta))^2 + \beta u'(c_1)f''(k)} \\
&> 0.
\end{aligned}
$$

In the case where $\lambda_b = 0$ we have $\mu_0 = \beta^{-1}\mu_1$ and hence $c_0 = c_1$ and the agent is unconstrained. The first order condition with respect to i_n then implies that

$$
1 = \beta(\alpha k^{\alpha-1} + p_u(1-\delta)),
$$

which means that investment is constant and $\bar{\bar{k}} = (\alpha^{-1}(\beta^{-1} - p_u(1-\delta)))^{\frac{1}{\alpha-1}}$. Notice also that in an economy with credit constrained pricing $\bar{k} < \bar{\bar{k}}$. At the lower boundary of this region, savings b equal $\beta\theta p_u\bar{k}(1-\delta)$ and since $u'(c_0) = u'(c_1)$ we have

$$
u'(e - \bar{\bar{k}}(1-\beta\theta p_u(1-\delta))) = u'(\bar{\bar{k}}^\alpha + p_u\bar{\bar{k}}(1-\delta)(1-\theta))
$$

which implicitly defines $\bar{\bar{e}} = \bar{\bar{k}}(1-\beta\theta p_u(1-\delta)) + \bar{\bar{k}}^\alpha + p_u\bar{\bar{k}}(1-\delta)(1-\theta)$. In an economy with credit constrained pricing $\bar{e}_n < \bar{\bar{e}}$.

Since the maximizing choices are continuous functions, we conclude that the agent invests in used capital only below $\bar{e}_u$, invests in new and used capital between $\bar{e}_u$ and

$\bar{e}_n$, and in new capital only above $\bar{e}_n$. Moreover, the agent is credit constrained below $\bar{\bar{e}}$ and unconstrained above that value. $\square$

Proof of Proposition 4. Recall from equation (12) that

$$\mu_1 m_u + \lambda_n - \lambda_u = \mu_0(1 - p_u) = \mu_1 m_u + \lambda_b m_u$$

where the second equality uses the fact that $\mu_0 = \mu_1\beta^{-1} + \lambda_b\beta^{-1}$ and $p_u + \beta m_u = 1$. Hence, $\lambda_b m_u = \lambda_n - \lambda_u$. But this implies that $\lambda_u = 0$, $\forall e \in \mathcal{E}$, since λ_n and λ_u can not both be strictly positive. Moreover, $\lambda_n = 0$ if and only if $\lambda_b = 0$.

Suppose $\lambda_b > 0$ and hence $b = \beta\theta p_u i_u(1-\delta)$ and $i_n = 0$. Then, i_u solves equation (13) and, totally differentiating, we have $\frac{di_u}{de} > 0$ (see equation (14)).

Suppose $\lambda_b = 0$, and hence $\lambda_n = 0$ and $\mu_0 = \mu_1\beta^{-1}$. Equation (11) then implies that $1 = \beta(\alpha k^{\alpha-1} + p_u(1-\delta))$ which is solved by $\bar{k} = \left(\alpha^{-1}\left(\beta^{-1} - p_u(1-\delta)\right)\right)^{\frac{1}{\alpha-1}}$. Now agents in this range are indifferent between investing in new and used capital at the margin. However, we can determine the minimum used capital investment that is required for given e. At the margin, investing in new capital instead of used capital is equivalent to investing in used capital and reducing borrowing by the difference $1 - p_u$. Thus, the way to obtain a capital stock of $\bar{k}$ while saving the minimum amount is by investing in used capital only. At the lower boundary of the region, the agent invests in used capital only and borrowing is $b^{max} = \beta\theta p_u\bar{k}(1-\delta)$. Moreover, since $\lambda_b = 0$, we have

$$u'(e - p_u\bar{k}(1 - \beta\theta(1-\delta))) = u'(\bar{k}^\alpha + p_u\bar{k}(1-\delta)(1-\theta) - m_u\bar{k})$$

which defines $\bar{e}_u = p_u\bar{k}(1 - \beta\theta(1-\delta)) + \bar{k}^\alpha + p_u\bar{k}(1-\delta)(1-\theta) - m_u\bar{k}$. Thus, the minimum used capital investment at $\bar{e}_u$ is $i_u^{min} = \bar{k}$. Above $\bar{e}_u$, the minimum used capital investment, which implies $b^{max} = \beta\theta p_u\bar{k}(1-\delta)$, decreases since c_1 must be increasing in e and $\frac{dc_1}{de} = -m_u\frac{di_u^{min}}{de}$. At the upper boundary of this region, the agent invests in new capital only and $b^{max} = \beta\theta p_u\bar{k}(1-\delta)$, and

$$u'(e - \bar{k}(1 - \beta\theta p_u(1-\delta))) = u'(\bar{k}^\alpha + p_u\bar{k}(1-\delta)(1-\theta))$$

which is solved by $\bar{e}_n = \bar{k}(1 - \beta\theta p_u(1-\delta)) + \bar{k}^\alpha + p_u\bar{k}(1-\delta)(1-\theta) > \bar{e}_u$. Above $\bar{e}_n$, $i_u^{min} = 0$, $i_n^{max} = \bar{k}$, and $b^{max} < \beta\theta p_u\bar{k}(1-\delta)$. $\square$

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Table 1: Parameter Values for Example Economies

Preferences	β $\quad$ σ	
	0.96 $\quad$ 2.00	
Technology	α $\quad$ δ $\quad$ m_u	
	0.33 $\quad$ 0.12 $\quad$ 0.50	
Collateralization Rate	θ	
	0.20	
Discretized State Space	i_u, i_n	b
	[0 : 0.002 : 0.5]	[−0.2 : 0.002 : 0, 0.001 : 0.001 : 0.05]
	Distribution of Internal Funds	
Economy with Credit	e	$\pi(e)$
Constrained Pricing	[0.05 : 0.05 : 1.75]	$\propto$ [exp(−0.05), . . . , exp(−1.75)]
Economy with	e	$\pi(e)$
Unconstrained Pricing	[0.05 : 0.05 : 1.75]	[1/35, . . . , 1/35]

Table 2: Equilibrium Implications

Panel A: Economy with Credit Constrained Pricing

Price of Used Capital	p_u		
	0.5485		
Cutoff Levels of Internal Funds	$\bar{e}_u$	$\bar{e}_n$	$\bar{\bar{e}}$
	0.8469	1.2134	1.3604
Levels of Capital	$\bar{k}$	$\bar{\bar{k}}$	
	0.3914	0.4554	

Panel B: Economy with Unconstrained Pricing

Price of Used Capital	p_u	
	0.5200	
Cutoff Levels of Internal Funds	$\bar{e}_u$	$\bar{e}_n$
	0.8820	1.3001
Level of Capital	$\bar{k}$	
	0.4265	

Table 3: Fraction of Trucks Purchased Used

The table shows the fraction of trucks purchased used as percentage of all trucks purchased new or used for all trucks and depending on the fleet size, which is the number of trucks and trailers operated by a truck owner for his/her entire operation. The table also shows the 25th percentile, median, and 75th percentile of the fraction of trucks purchased used across 32 different body types of trucks (e.g., pickup, panel or van, ...). Data is from the public use micro data file of the 1997 VIUS. We report results for trucks reported as operated for business use only, which are about 25% of the overall sample of 131,000 trucks.

		All Trucks	By Body Type		
			25th Percentile	Median	75th Percentile
Overall		50.49%	41.98%	52.07%	67.07%
By Fleet Size	1	56.97%	64.26%	75.19%	85.57%
	2-5	56.61%	54.78%	69.31%	76.52%
	6-9	55.57%	51.92%	57.54%	71.95%
	10-24	37.96%	42.00%	49.04%	63.39%
	25-99	33.62%	32.20%	46.75%	51.45%
	100-499	24.08%	23.20%	29.89%	41.75%
	500-999	17.79%	14.60%	30.03%	41.59%
	1,000-4,999	12.77%	7.98%	13.67%	24.23%
	5,000-9,999	2.70%	2.51%	17.43%	28.42%
	10,000 or more	4.08%	4.43%	7.00%	15.67%

Table 4: Used Capital Expenditures on Structures and Equipment by Type

The table shows the main types of used structures and equipment expenditures (as a fraction of aggregate expenditures) and the percentage used (as a fraction of total expenditures) by type. We report types which make up 5% or more of aggregate expenditures. The data is from the 1998 ACES report.

Used Structures

Type	Fraction of Aggregate Capital Expenditures on Used Structures		Fraction Used Structures as Percent of Total Capital Expenditures by Type
Commercial Buildings	34.7%	(55% of which is multiretail stores)	24.8%
Offices	21.9%		20.1%
Residential Buildings	10.4%		34.1%
Hotels and Motels	8.9%		35.3%
Health Care Facilities	7.4%		11.6%
Industrial Buildings	5.8%		5.7%

Used Equipment

Type	Fraction of Aggregate Capital Expenditures on Used Equipment		Fraction Used Equipment as Percent of Total Capital Expenditures by Type
Transportation Equipment	41.5%	(42% of which is cars and trucks and 33% aerospace products and parts)	6.3%
Industrial Equipment	20.7%	(49% of which is special industrial machinery)	3.5%
Miscellaneous Equipment	17.9%	(50% of which is construction machinery)	7.9%
Information-processing Equipment	13.0%	(49% of which is computer and peripheral equipment)	1.7%
Energy, Electrical and Related Equipment	5.7%	(65% of which is mining and oil and gas field machinery and equipment)	4.5%

Table 5: Used Capital Expenditures by Industry

The table shows the used capital, used structures, and used equipment expenditures (as a fraction of total expenditures) by industry. The data is from the 1998 ACES as restated in Table 4c of the 1999 ACES report.

Industry (NAICS Code in Parenthesis)	Used Capital as Fraction of Total Capital Expenditures	Used Structures as Fraction of Total Structures Expenditures	Used Equipment as Fraction of Total Equipment Expenditures
Construction (23)	25.2%	32.8%	22.5%
Real Estate and Rental and Leasing (53)	16.7%	34.4%	3.2%
Accommodation and Food Services (72)	11.6%	13.6%	8.8%
Transportation and Warehousing (48-49)	10.7%	5.1%	12.7%
Finance and Insurance (52)	9.5%	38.1%	1.0%
Administrative and Support and Waste Management (56)	7.8%	12.7%	5.4%
Mining (21)	7.6%	6.8%	9.3%
Health Care and Social Assistance (62)	7.0%	11.0%	2.9%
Wholesale Trade (42)	6.7%	9.9%	5.6%
Retail Trade (44-45)	6.7%	8.0%	5.6%
Other Services (except Public Administration) (81)	5.1%	3.3%	8.6%
Manufacturing (Nondurables) (31, 322-326)	3.8%	4.8%	3.4%
Professional, Scientific, and Technical Services (54)	3.8%	6.4%	3.0%
Manufacturing (Durables) (321, 327, 33)	3.3%	4.9%	3.2%
Educational Services (61)	3.3%	4.1%	1.3%
Utilities (22)	2.7%	4.3%	1.0%
Information (51)	1.5%	2.0%	1.3%

Table 6: Capital Expenditures for New and Used Capital: Companies with and without Employees

The table describes the composition of capital expenditures on new and used structures and equipment for companies with and without employees. Total expenditures is the sum of structures and equipment. Figures represent fraction of capital expenditures on used capital (as percent of total capital expenditures), used structures (as percent of total capital expenditures on structures), used equipment (as percent of total capital expenditures on equipment), and structures (as percent of total capital expenditures) for all companies, and companies with and without employees. Data is from the 1996-2002 ACES reports. We use restated data wherever possible.

	Year							Average
	1996	1997	1998	1999	2000	2001	2002	
Capital Expenditures on Used Capital as Percent of Total Capital Expenditures								
All Companies	7.1%	6.3%	8.3%	5.8%	7.0%	6.0%	8.1%	6.9%
Without Employees	24.0%	24.2%	19.0%	25.9%	26.4%	30.8%	30.7%	25.9%
With Employees	4.7%	4.0%	7.4%	4.3%	5.7%	4.7%	6.1%	5.3%
Capital Expenditures on Used Structures as Percent of Total Expenditures on Structures								
All Companies	8.4%	7.0%	13.6%	7.5%	9.6%	7.6%	11.8%	9.4%
Without Employees	18.9%	20.9%	15.0%	22.3%	24.1%	33.3%	36.2%	24.4%
With Employees	6.2%	4.6%	13.4%	6.0%	8.4%	6.4%	9.1%	7.7%
Capital Expenditures on Used Equipment as Percent of Total Expenditures on Equipment								
All Companies	6.7%	6.1%	5.6%	5.2%	5.8%	5.2%	6.1%	5.8%
Without Employees	27.4%	26.0%	21.5%	27.8%	27.8%	29.7%	26.8%	26.7%
With Employees	4.2%	3.7%	4.4%	3.6%	4.5%	3.9%	4.5%	4.1%
Capital Expenditures on Structures as Percent of Total Capital Expenditures								
All Companies	29.7%	31.4%	33.9%	30.6%	31.4%	32.8%	34.6%	32.1%
Without Employees	39.1%	37.3%	38.7%	36.3%	37.0%	30.9%	41.4%	37.2%
With Employees	28.9%	30.5%	33.5%	30.1%	31.0%	32.9%	34.0%	31.6%

Table 7: Ratio of Used Capital Expenditures to Total Capital Expenditures across Asset Deciles

The table describes the amount of capital expenditures on used capital as percentage of total capital expenditures for firms with employees across asset deciles for capital overall and for structures and equipment separately. We use the 1993-2002 ACES micro data for all industries. We use the firm assets at the beginning of the year as our measure of size and exclude firms with zero assets. We exclude observations for which used capital expenditures on capital overall, structures, and equipment are missing as well as observations for which capital expenditures on structures or equipment are zero. There are an average of 4479 observations per year. We compute the average ratio of used capital expenditures to total capital expenditures in each size decile for each year and report the average of these average ratios across years for each size decile. We also report the lower cutoffs for each decile.

Asset Deciles	Decile Cutoff (in millions)	Used Capital Overall (in percent)	Used Structures (in percent)	Used Equipment (in percent)
1st	0	27.79%	28.77%	26.21%
2nd	0.10	20.17%	21.69%	17.32%
3rd	0.36	18.51%	21.43%	15.36%
4th	1.04	17.13%	20.20%	14.46%
5th	2.94	16.14%	20.08%	12.97%
6th	7.55	15.07%	19.04%	12.44%
7th	16.89	12.69%	16.15%	10.64%
8th	34.46	12.16%	15.80%	9.72%
9th	69.24	11.22%	15.33%	9.18%
10th	186.55	10.10%	13.04%	8.34%

Table 8: Descriptive Statistics

The table shows the descriptive statistics for the variables used in the regressions of the fraction of capital expenditures on used capital on various financial and control variables. Data is micro data from a cross section of firms from the 1998 ACES for the dependent variable, used capital expenditures over total capital expenditures, firm age, and for the industry dummies, and from Compustat for financial variables. Used capital expenditures and total capital expenditures are from Item 2 of the 1998 ACES (row 22 and 20, respectively). Assets are Item 6 (Assets - Total/Liabilities and Stockholders' Equity - Total); dividends are Item 21 (Dividends - Common) plus (where available) Item 19 (Dividends - Preferred); long-term debt is Item 9 (Long-Term Debt - Total); cash flow is Item 18 (Income Before Extraordinary Items) plus Item 14 (Depreciation and Amortization); Tobin's q is Item 6 plus Item 24 (Price - Close) times Item 25 (Common Shares Outstanding) minus Item 60 (Common Equity - Total) minus Item 74 (Deferred Taxes - Balance Sheet) all divided by Item 6; cash is Item 1 (Cash and Short-Term Investments). The firm age variable is the age of the firm according to Census data. The mean and standard deviation of sales growth is computed using the logarithmic growth rates of Item 12 (Net Sales) using data for years 1993 to 1998. The average tax rate is Item 16 (Income Taxes) divided by the sum of Item 16 and Item 18, set to the 1st percentile value if Item 16 is negative, and to the 99th percentile value if Item 16 is positive and Item 18 negative. The marginal tax rate is the before interest expense marginal tax rate constructed by John Graham (see, e.g., Graham, Lemmon, and Schallheim (1998)). PP&E is Item 8 (Property, Plant & Equipment - Net) and employees are Item 29 (Employees). R&D expense is Item 46 (Research & Development Expense). All variables (except firm age and the marginal tax rate) are Winsorized at the 1st and 99th percentile.

Dependent Variables	Observations	Mean	Std. Dev.	Median
used to total capital expenditures overall	1101	12%	21%	2%
used to total capital expenditures on structures	838	21%	32%	0%
used to total capital expenditures on equipment	883	10%	19%	1%
Independent Variables				
log(assets)	1101	6.59	1.83	6.50
dividends/assets	1101	1%	2%	0%
long-term debt/assets	1098	24%	21%	20%
cash flow/assets	1076	7%	9%	8%
q	892	1.62	1.04	1.26
cash/assets	1101	8%	11%	3%
firm age	1096	16.85	7.07	22
std. dev. sales growth	805	13%	11%	10%
average tax rate	1068	33%	17%	37%
marginal tax rate	805	31%	9%	35%
PP&E/employees (in millions)	978	0.106	0.240	0.035
R&D expense/sales	1064	1.52%	4.31%	0%
sales/employees (in millions)	1001	0.232	0.224	0.169
mean sales growth	905	12%	15%	10%

Table 9: Regression Results: Fraction Used Capital Expenditures for Capital Overall

The table shows the coefficients of a regression of the fraction of capital expenditures on used capital (for capital overall) on various financial and control variables (controlling for industry dummies at the three digit NAICS code level). Heteroscedasticity corrected standard errors are in parenthesis. Data is micro data from a cross section of firms from the 1998 ACES for the dependent variable, used capital expenditures over total capital expenditures, firm age, and the industry dummies, and from Compustat for financial variables, tax variables, and the standard deviation of sales growth. For a detailed definition of the variables see the description in Table 8. Statistical significance at the 1%, 5%, and 10% level is indicated by ***, **, and *, respectively.

Regression	1	2	3	4	5	6	7	8	9	10	11
log(assets)	-0.0085**	-0.0098***	-0.0105***	-0.0142***	-0.0102***	-0.0181***	-0.0170***	-0.0147***	-0.0221***	-0.0179***	-0.0151***
	(0.0037)	(0.0036)	(0.0037)	(0.0040)	(0.0037)	(0.0041)	(0.0054)	(0.0039)	(0.0050)	(0.0052)	(0.0055)
dividends/assets	-0.6037**					-0.2504	-0.0265	-0.3582	-0.0090	-0.0706	0.0440
	(0.3022)					(0.3375)	(0.4547)	(0.3200)	(0.4381)	(0.4264)	(0.5016)
long-term debt/assets		0.0933**				0.1465***	0.1300***	0.1450***	0.1706***	0.1343***	0.1211**
		(0.0376)				(0.0444)	(0.0469)	(0.0448)	(0.0515)	(0.0423)	(0.0540)
cash flow/assets			0.0506			0.0996	0.1397	0.1310*	0.0851	0.1400	0.0759
			(0.0783)			(0.0812)	(0.1112)	(0.0726)	(0.1124)	(0.1035)	(0.1351)
q				0.0080		0.0156*	0.0117	0.0128*	0.0215**	0.0075	0.0119
				(0.0069)		(0.0080)	(0.0091)	(0.0074)	(0.0098)	(0.0083)	(0.0099)
cash/assets					-0.0908**	-0.0655	-0.0586	-0.0559	-0.0582	-0.0504	-0.0438
					(0.0450)	(0.0561)	(0.0738)	(0.0558)	(0.0708)	(0.0739)	(0.0800)
firm age							-0.0018				-0.0024
							(0.0016)				(0.0018)
σ(sales growth)							0.1193				0.1057
							(0.0918)				(0.1001)
avg. tax rate								-0.0368			-0.0389
								(0.0397)			(0.0556)
mrg. tax rate									0.0552		
									(0.0982)		
PP&E/employees										0.0412	0.0595
										(0.0677)	(0.0750)
R&D expense/sales										0.1556	0.1227
										(0.1944)	(0.2251)
sales/employees										-0.0984*	-0.1547**
										(0.0542)	(0.0673)
μ(sales growth)										0.0834	0.0517
										(0.0643)	(0.0934)
$adj.R^2$	11.70%	12.27%	7.71%	14.68%	11.69%	12.59%	8.72%	11.21%	14.20%	12.03%	10.44%
Observations	1101	1098	1076	892	1101	871	638	839	710	671	578

Table 10: Regression Results: Fraction Used Capital Expenditures for Structures

The table shows the coefficients of a regression of the fraction of capital expenditures on used capital (for structures) on various financial and control variables (controlling for industry dummies at the three digit NAICS code level). Heteroscedasticity corrected standard errors are in parenthesis. Data is micro data from a cross section of firms from the 1998 ACES for the dependent variable, used capital expenditures over total capital expenditures, firm age, and the industry dummies, and from Compustat for financial variables, tax variables, and the standard deviation of sales growth. For a detailed definition of the variables see the description in Table 8. Statistical significance at the 1%, 5%, and 10% level is indicated by ***, **, and *, respectively.

Regression	1	2	3	4	5	6	7	8	9	10	11
log(assets)	-0.0134*	-0.0150**	-0.0163**	-0.0255***	-0.0151**	-0.0299***	-0.0270**	-0.0270***	-0.0300***	-0.0294***	-0.0266**
	(0.0072)	(0.0072)	(0.0072)	(0.0082)	(0.0074)	(0.0081)	(0.0105)	(0.0083)	(0.0094)	(0.0105)	(0.0115)
dividends/assets	-1.2835**					-0.7835	-0.8293	-0.8734	-0.5626	-0.9473	-0.7366
	(0.5399)					(0.5862)	(0.7653)	(0.6042)	(0.7952)	(0.7259)	(0.8231)
long-term debt/assets		0.1616**				0.1874**	0.1057	0.1414	0.2947***	0.1067	0.0269
		(0.0757)				(0.0879)	(0.1101)	(0.0885)	(0.1012)	(0.1000)	(0.1133)
cash flow/assets			0.0083			0.1856	0.2898	0.0851	0.3102	0.3260	0.2451
			(0.1847)			(0.1959)	(0.2593)	(0.2059)	(0.2720)	(0.2276)	(0.2632)
q				0.0017		0.0118	0.0127	0.0153	0.0167	-0.0047	0.0019
				(0.0137)		(0.0156)	(0.0173)	(0.0157)	(0.0179)	(0.0185)	(0.0186)
cash/assets					-0.0486	0.0140	-0.0303	0.0187	0.1913	-0.1165	-0.2159
					(0.1178)	(0.1500)	(0.2122)	(0.1519)	(0.2005)	(0.1990)	(0.2139)
firm age							-0.0030				-0.0020
							(0.0028)				(0.0029)
σ(sales growth)							0.1359				0.1959
							(0.1642)				(0.1807)
avg. tax rate								-0.2219***			-0.2394**
								(0.0823)			(0.1130)
mrg. tax rate									-0.1544		
									(0.1963)		
PP&E/employees										0.0768	0.0437
										(0.1143)	(0.1370)
R&D expense/sales										1.2840**	1.5336**
										(0.6315)	(0.6660)
sales/employees										-0.2120**	-0.2622**
										(0.0949)	(0.1245)
μ(sales growth)										0.1570	0.1030
										(0.1149)	(0.1441)
$adj.R^2$	2.69%	3.08%	0.92%	4.30%	2.24%	3.89%	0.40%	6.10%	2.28%	3.49%	4.88%
Observations	838	835	815	664	838	643	490	623	525	504	447

Table 11: Regression Results: Fraction Used Capital Expenditures for Equipment

The table shows the coefficients of a regression of the fraction of capital expenditures on used capital (for equipment) on various financial and control variables (controlling for industry dummies at the three digit NAICS code level). Heteroscedasticity corrected standard errors are in parenthesis. Data is micro data from a cross section of firms from the 1998 ACES for the dependent variable, used capital expenditures over total capital expenditures, firm age, and the industry dummies, and from Compustat for financial variables, tax variables, and the standard deviation of sales growth. For a detailed definition of the variables see the description in Table 8. Statistical significance at the 1%, 5%, and 10% level is indicated by ***, **, and *, respectively.

Regression	1	2	3	4	5	6	7	8	9	10	11
log(assets)	-0.0087**	-0.0093**	-0.0097***	-0.0109***	-0.0097***	-0.0158***	-0.0184***	-0.0143***	-0.0230***	-0.0222***	-0.0196***
	(0.0038)	(0.0037)	(0.0038)	(0.0041)	(0.0038)	(0.0043)	(0.0056)	(0.0043)	(0.0055)	(0.0053)	(0.0058)
dividends/assets	-0.0315					0.2424	0.4276	0.2204	0.4658	0.6056	0.6247
	(0.3157)					(0.3572)	(0.5000)	(0.3395)	(0.4316)	(0.4637)	(0.5371)
long-term debt/assets		0.1158***				0.1425***	0.1313**	0.1555***	0.1433***	0.1500***	0.1210**
		(0.0398)				(0.0442)	(0.0519)	(0.0444)	(0.0506)	(0.0471)	(0.0587)
cash flow/assets			0.0588			0.1431*	0.1864*	0.1741**	0.0752	0.1503	0.1667
			(0.0794)			(0.0763)	(0.1052)	(0.0737)	(0.0946)	(0.1021)	(0.1391)
q				0.0040		0.0061	0.0039	0.0057	0.0132	0.0012	0.0025
				(0.0072)		(0.0080)	(0.0103)	(0.0080)	(0.0100)	(0.0091)	(0.0100)
cash/assets					-0.0973**	-0.0415	-0.0832	-0.0361	-0.0881	-0.0611	-0.1037
					(0.0482)	(0.0564)	(0.0769)	(0.0540)	(0.0639)	(0.0717)	(0.0864)
firm age							-0.0016				-0.0027
							(0.0019)				(0.0021)
σ(sales growth)							0.2064*				0.0956
							(0.1065)				(0.1146)
avg. tax rate								-0.0086			-0.0496
								(0.0395)			(0.0569)
mrg. tax rate									0.1307		
									(0.1052)		
PP&E/employees										0.0678	0.1195**
										(0.0498)	(0.0555)
R&D expense/sales										0.1152	0.0197
										(0.1962)	(0.2422)
sales/employees										-0.0781**	-0.1309**
										(0.0380)	(0.0535)
μ(sales growth)										0.0661	0.0254
										(0.0739)	(0.1082)
$adj.R^2$	10.71%	12.01%	10.95%	12.02%	11.00%	14.34%	11.59%	12.78%	15.98%	15.71%	11.89%
Observations	883	883	871	715	883	706	523	682	577	550	473

Figure 1: Investment in New and Used Capital in an Economy with Credit Constrained Pricing

Top Left Panel: Investment in new capital (dash dotted), used capital (solid), and total investment (dotted) as a function of the amount of internal funds. Middle Left Panel: Investment in used capital as percentage of total investment. Bottom Left Panel: Agent specific shadow price of new capital (dotted) and used capital (solid). Top Right Panel: Borrowing. Middle Right Panel: Multiplier on the borrowing constraint $\lambda_b(e)$ (normalized by the marginal utility of consumption at time 0) as a function of the amount of internal funds.

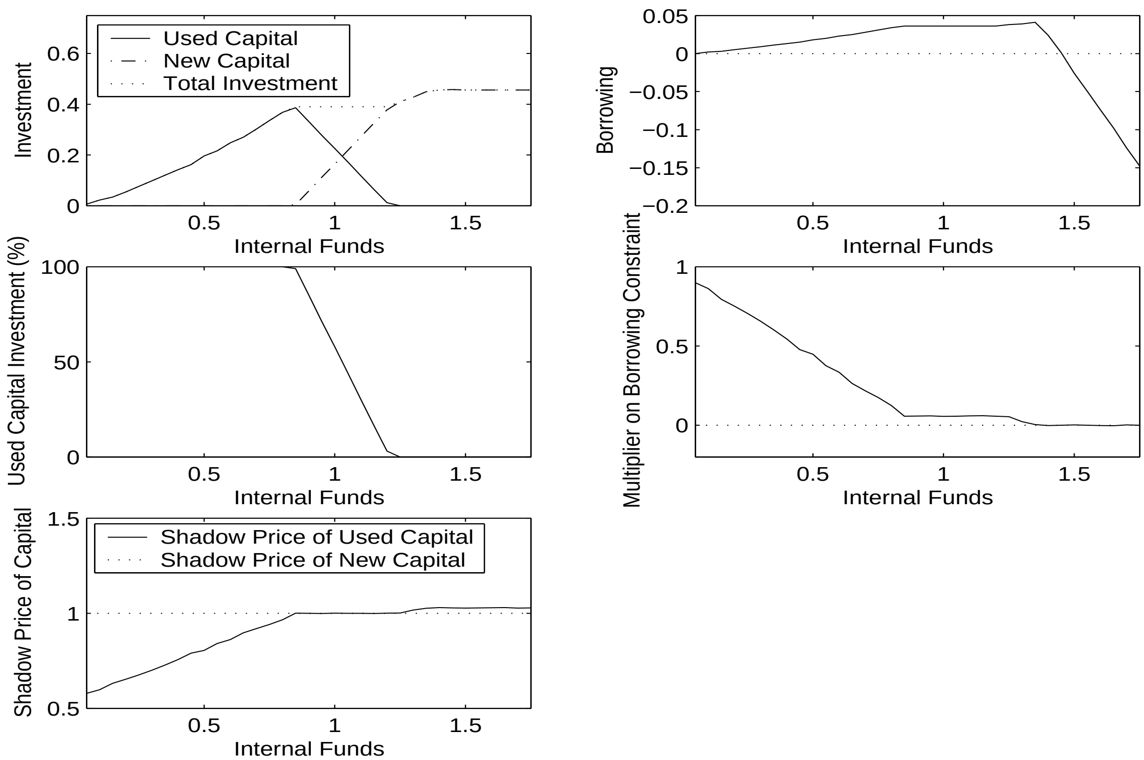

Figure 2: Investment in New and Used Capital in an Economy with Unconstrained Pricing

Top Left Panel: Maximum investment in new capital (dash dotted), minimum investment in used capital (solid), and total investment (dotted) as a function of the amount of internal funds. Middle Left Panel: Minimum investment in used capital as percentage of total investment. Bottom Left Panel: Agent specific shadow price of new capital (dotted) and used capital (solid). Top Right Panel: Maximum borrowing. Middle Right: Multiplier on the borrowing constraint $\lambda_b(e)$ (normalized by the marginal utility of consumption at time 0) as a function of the amount of internal funds.

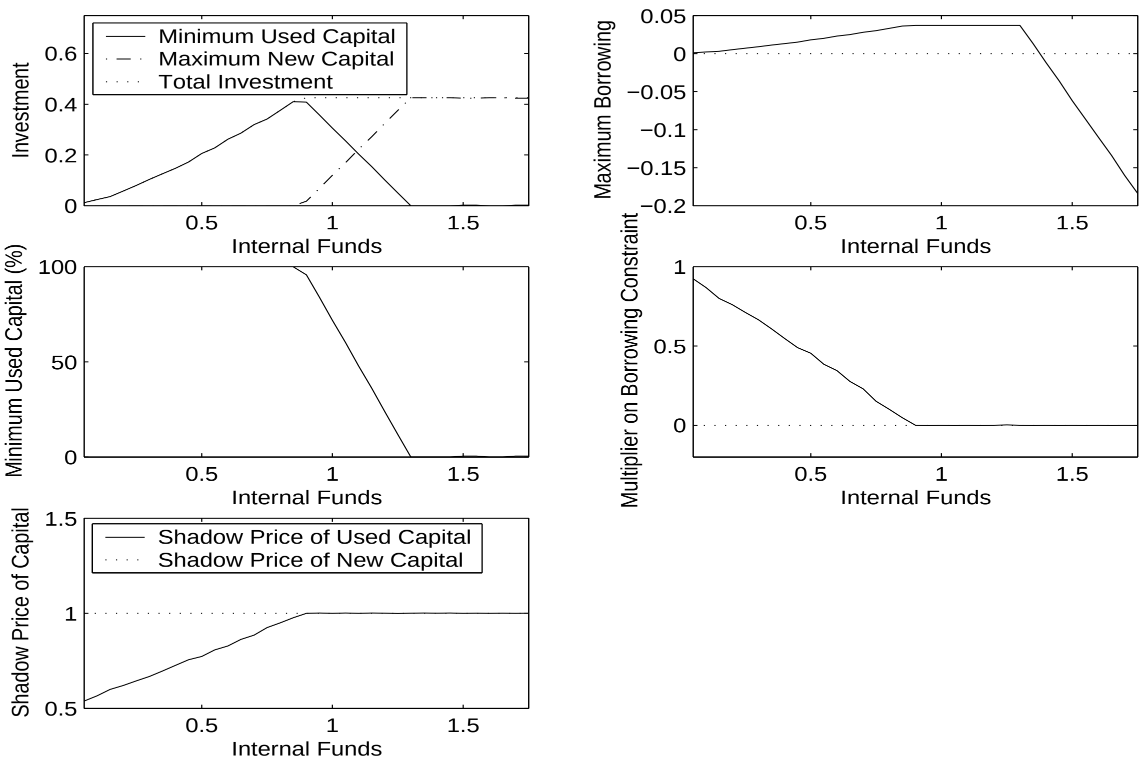

Figure 3: Fraction of Trucks Purchased Used versus Fleet Size

Plotted series are the fraction of trucks purchased used as percentage of all trucks purchased new or used graphed against the natural logarithm of the fleet size, which is the number of trucks and trailers operated by a truck owner for his/her entire operation. We use the midpoint of the reporting category as the fleet size. Solid bold line is the fraction of all trucks purchased used and dotted lines are fraction of trucks purchased used for 32 different body types of trucks (e.g., pickup, panel or van, . . .). Data is from the public use micro data file of the 1997 VIUS. We report results for trucks reported as operated for business use only.

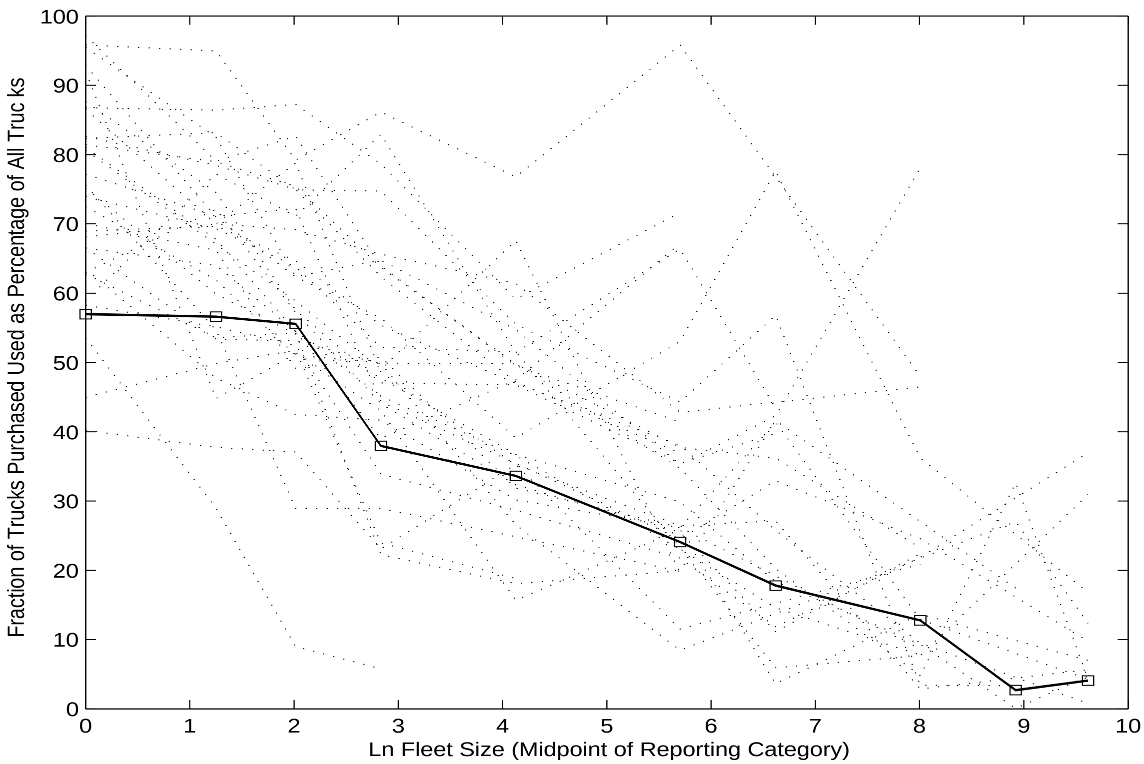

Figure 4: Fraction of Used Capital Expenditures across Asset Deciles

Fraction of used capital expenditures relative to total capital expenditures in percent graphed across asset deciles: Percentage used capital overall (solid), percentage used structures (dashed), and percentage used equipment (dash dotted). We use the 1993-2002 ACES micro data. See Table 7 for a detailed description of the data construction.