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Do average costs decline as firms grow?

Aytekin Ertan
aertan@london.edu

Stefan Lewellen
slewellen@london.edu

Jake Thomas
jake.thomas@yale.edu

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Abstract

It is common in business analyses to assume that costs grow at a slower rate than sales, especially during high growth phases, because of scale efficiencies. Relevant factors include increased bargaining power and the relatively fixed nature of some costs. Growth should thus be associated with declining average costs/sales. We document how average costs/sales for different cost items evolve as firms grow, after they go public. To our surprise, we find that costs/sales remain relatively unchanged, even during the early post-IPO period when growth is high. We then repeat the analysis for other samples (such as private firms and overseas firms) and again find little evidence of scale efficiencies. We identify implications of this result, and speculate about why it is observed.

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I. Introduction

Analyses underlying important business decisions—including whether to invest or whether to add a new product/customer—routinely project performance improvements as organizations grow, particularly when growth is high. These improvements, which we label s*cale efficiencies*, cause average costs/revenues (*CR* hereafter) to decline and profit margins (*PM* or profits/revenues) to increase with scale. We document the magnitude of scale efficiencies, as well as how much they vary across different cost items and different samples. Our motivations to study the evolution of CR is described below.

Scale efficiencies are attributed to various sources. The most common source is costs that remain relatively fixed as scale increases. Consider, for example, the costs of information technology, inside/outside legal counsel, regulatory compliance, and fees paid to consultants and auditors. While these costs grow in the long run, they are expected to grow at a slower rate than sales. Another common source of scale efficiencies is the increased bargaining power—over customers and suppliers—associated with scale. Higher bargaining power leads to lower input and higher output prices.

Even though scale efficiencies are commonly described as *economies of scale*, the two concepts are distinct. Economies of scale (*EOS*) refer to cases where long-run marginal costs per *unit* of output are lower than long-run average costs (e.g., Pindyck and Rubinfeld, 2005). In equilibrium, firms operate at the scale where long-run average costs are minimized, and equal long-run marginal costs. Long-run costs, both marginal and average, for other levels of scale are not observed. Economists compare cost structures across firms, each operating at their optimum scale. In contrast, financial analyses—conducted by managers and investors—focus on whether the *observed* average cost per dollar of *revenue* (*CR*) declines as scale increases. Firms grow gradually toward efficient scale, for a variety of reasons including constraints on growth that can reasonably be achieved. We investigate how cost structures evolve for each firm over time as they grow. Also, we examine costs per revenue dollar, not per unit of output. Consider the case of a firm that produces laptops in an environment where output grows but selling prices and input costs decline. Economies of scale focus on the lower cost per laptop, whereas we focus on whether the lower cost per laptop is offset by lower selling prices.

Our first motivation to study the evolution of *CR* is to document variation in scale efficiencies along a number of dimensions. Even though scale efficiencies are commonly invoked in practice, there is little large-scale evidence on the evolution of *CR*, especially at the firm level. Are scale efficiencies greater—does *CR* decline faster—for early-stage firms relative to more mature firms? How do scale efficiencies vary across industries, across public and private firms, across different markets, and so on? Even though our exploration is descriptive, not guided by theory, documenting empirical regularities should spur theory development.

Despite the emphasis on marginal revenues and costs for business decisions, there are instances where organizations emphasize average costs or assume that marginal costs in the long-run equal average costs. In particular, the CFO's office often adds on to marginal costs an allocation of fixed costs for different resources used, averaged over total consumption of that resource).[1] This reliance on "full" costing is known to create conflicts. For example, product managers seeking to introduce a new product that uses excess capacity complain about having to cover the costs of excess capacity. Even though CFO's justify the use of average costs by suggesting that excess capacity currently available is eventually used up, there is a concern that

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[1] Two other examples of the use of average costs in practice are as follows. First, projections for discounted cash flow valuations implicitly assume that *CR* remains constant past the terminal date; i.e., long-run marginal costs equal average costs. Second, Activity Based Costing uses average costs of different transactions to proxy for long-run marginal costs (e.g., Cooper and Kaplan, 1988).

the use of average costs creates distortions.[2] Our second motivation to study the evolution of average *CR* as firms grow is to offer evidence on the extent of this distortion.

For our primary analysis, we follow a sample of US firms since their IPO (initial public offering) date, and track how average *CR* varies as they age. We consider four broad cost categories: production costs or costs of goods sold (*COGS*); selling and administrative costs (*SG&A*); depreciation and amortization (*D&A*), and financing costs, represented by levels of debt plus equity used to finance net operating assets (*NOA*). We also consider three *PM* measures: earnings before interest and tax (*EBIT*), net income (*NI*) and economic income (*EI*).[3] All costs and profits are deflated by sales. We also look for variation across seven broad industry sectors: Energy, Materials, Industrials, Consumer Discretionary, Consumer Staples, Health Care, and Information Technology.

We find surprising results: Contrary to our expectation and the common wisdom that scale efficiencies are pervasive, average *CR* does not appear to decline and average *PM* does not appear to increase as firms grow. Not only are the coefficients insignificant for all the cost and profit measures we track, they are often of the wrong sign. We find similar results for young cohorts, when growth is highest and scale efficiencies are also assumed to be high. Similar results are observed in most sectors.

To confirm the robustness of our finding, we repeat the analyses for different samples. We investigate a larger sample of US public firms that includes "non-IPO firms"—firms that had an IPO date before they enter our sample window. We also investigate much larger samples of public

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[2] To be sure, full costing may be designed to remind decision-makers to focus on long-run, rather than short-run, marginal costs. See Zimmerman (1979) for a deeper discussion.

[3] Accounting or GAAP net income deducts most costs, including the cost of debt, but does not deduct the cost of equity. This omission is due to the difficulty associated with determining an objective estimate of the cost of equity. Economic income deducts a charge for the cost of equity. See Table 1 for more details.

firms around the globe and private firms in Europe. Overall, the finding that CR does not decline and PM does not increase as firms grow appears to be a robust, general result.

The finding that *CR* remains relatively constant is supported by supplementary analyses which suggest that *CR* appears to be well-described by a random walk process, with no drift. Predicted values for costs and individual operating asset items, based on last year's *CR*, are close to observed values for most firm-years. For example, the first (third) quartile of prediction errors for COGS is -2.1 (+2.0) percent of observed COGS.

We examine changes in *CR* and *PM* around M&A transactions to confirm that scale efficiencies are observed when they are more certain. These transactions increase scale and the synergies motivating these transactions are for the main part cast in terms of scale efficiencies. We find that *PM* increases significantly for these transactions, relative to a control group of non-merging firms from the same industry.[4] Finding significant changes in performance using our methodology for this M&A sample alleviates concerns that the insignificant results observed for the IPO sample are due to our tests lacking statistical power.

Our final result relates to productivity and returns to scale. We estimate the Cobb-Douglas production function for different age cohorts, based on three inputs: dollars of fixed assets, number of employees, and dollars of capitalized R&D. Again, there is little evidence that the sum of the exponents on the three factor inputs or the total factor productivity increases as firms age.

The first implication of our results is that scale efficiencies are not as easily obtained as is commonly assumed. Decisions based on marginal costs should be scrutinized carefully to confirm that excluded fixed costs are indeed unlikely to change over the long-run. More generally, the

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[4] The prior literature has recognized that these transactions are not random and changes in performance around the transaction should properly be compared against the counterfactual of changes in performance that would have been observed if the transaction did not occur. The approach commonly followed in the literature is to compare performance changes around the transaction with performance changes for control firms from the same industry.

teaching of concepts based on short-run cost behavior—fixed/variable costs, contribution margins, and breakeven analysis—should be tempered by evidence on patterns observed for average costs/sales. Second, finding that costs grow proportionately with sales suggests that average costs are in fact a reasonable proxy for long-run marginal costs. The practice of charging users for average costs of resources does not create the distortions created by average costs exceeding marginal costs. Third, projections should consider an alternative approach: project sales first, and then use the historic relations between different line items and sales to project into the future. Finally, our results provide a complementary perspective to that in the vast literatures on economies of scale, returns to scale, and productivity.[5] Despite differences between these concepts and the scale efficiencies we study, our comprehensive analysis of firm-level costs versus growth may be relevant for those literatures.

A direct interpretation of our results is that at an intrinsic level costs/sales do not decline as firms grow. But we cannot rule out the possibility that costs/sales do in fact decline with growth but other factors offset the effects of that decline. For example, it is possible that competition causes firms to pass through to customers any scale efficiencies that arise. Another possibility is that the budgeting process allocates increased resources to different costs lines in proportion to sales growth and those resources are spent because of a "use it or lose it" mentality.

The rest of the paper is organized as follows. Section 2 discusses scale efficiencies—the construct and empirical measures—and its relation to the efficiency measures from economics. Section 3 describes our methodology, sample and relevant statistics. Section 4 investigates how

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[5] Returns to scale are defined as the rate at which output increases as inputs are increased proportionately (Pindyck and Rubinfeld (2005)). In contrast, total factor productivity captures shifts in the isoquants of firms' production functions (Syverson (2011)).

costs and profits, deflated by sales, vary as firms grow for our primary samples. Robustness analyses are reported in Section 5, and Section 6 concludes.

2. Relationships among scale, productivity, and long-run average costs

Three widely-used measures in the literature are *economies of scale*, *returns to scale*, and *productivity* (also known as total factor productivity, or *TFP*). For ease of exposition, we will use the textbook definitions of each measure, while noting that other (often more complicated) definitions also exist. To distinguish our construct of scale efficiency from these economics measures, we first distinguish our cost-to-revenue ratio (*CR*) from costs per unit of output.

2.1. Cost/Revenue ratio and costs per unit of output.

As illustrated in the earlier laptop example, economists are often concerned with the behavior of costs per unit of output whereas financial analyses focus mainly on costs (or profits) per dollar of revenue. To link *CR* to long-run average costs (*LRAC*) per unit of output, we consider a single-good firm with a Cobb-Douglas production technology defined over two inputs, capital (K) and labor (L), with costs r and w, respectively. The Cobb-Douglas technology links output quantities (q) to these inputs using the functional form $AK^{\alpha}L^{\beta}$, where A is a productivity factor, and α and β are output elasticities. Total costs, C, are given by

$$C = rK(q) + wL(q), \tag{1}$$

and the firm's dual problem of minimizing C for a given output quantity q can be stated as:

$$\min_{K,L} rK + wL \text{ s.t. } q = AK^{\alpha}L^{\beta} \text{ .} \tag{2}$$

When the firm is at its optimum, described by optimum quantities of capital and labor, K^* and L^*, long-run average cost (*LRAC*) is given by

$$LRAC = \frac{C}{q} = [rK^*(q) + wL^*(q)]/q \tag{3}$$

Substituting the values of *K** and *L** and defining $\theta = \alpha + \beta$ yields the following equation linking *LRAC* and scale (*q*), assuming prices are exogenous:

$$LRAC = \frac{\theta . r^{\frac{\alpha}{\theta}} . w^{\frac{\beta}{\theta}} . q^{\frac{1-\theta}{\theta}}}{(A\alpha^{\alpha}\beta^{\beta})^{\frac{1}{\theta}}} \tag{4}$$

We turn from average costs per unit (*LRAC*) to average costs per dollar of revenue (*CR*). As revenue (*R*) is the product of output quantity (*q*) and price (*p*), *CR* is *LRAC* divided by *p*

$$CR = \frac{\mathrm{C}}{\mathrm{R}} = \frac{\mathrm{C}}{\mathrm{p} * \mathrm{q}} = \frac{\mathrm{LRAC}}{\mathrm{p}} \tag{5}$$

Hence, a firm with lower *LRAC* will have a lower *CR*. If prices are constant, then *changes* in *CR* as scale increases will accurately capture corresponding changes in *LRAC*. However, if prices are not constant, changes in *CR* may understate or overstate changes in *LRAC*.[6]

2.2. Scale efficiencies and related economic concepts.

Scale efficiencies exist if *CR* declines as scale, measured by total revenues (*R*), increases. The cumulative effect of declines in the ratio of average costs to revenues should be reflected as increases in the ratio of profits to revenues, or profit margins (*PM*). That is, scale efficiencies imply

$$\frac{\partial CR}{\partial R} < 0 \text{ and } \frac{\partial PM}{\partial R} > 0 \tag{6}$$

The first concept from economics that is related to scale efficiencies is *economies of scale* (*EOS*). To use the textbook definition (Pindyck and Rubinfeld (2005)), *EOS* exists when the ratio of long-run marginal cost (*LRMC*) to *LRAC* is below one for a given production output. That is,

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[6] In some cases, changes in *CR* can even be of opposite sign to what would be expected given changes in *LRAC*. For example, consider a single-product firm that produces one unit of output per period at a cost of \$1 and a sales price of \$2. In this case, the firm's *LRAC* is equal to one and its *CR* equals 0.5. Now suppose that in the next period, the firm increases its output to two units at a total cost of \$1.50, but prices also fall to \$1 per unit. The firm's LRAC now falls to 1.5 / 2 = 0.75, but instead of falling (given the firm's greater efficiency), the firm's CR actually rises to 1.5 / (1*2) = 0.75. This simple example demonstrates the larger measurement problem researchers face in backing out *LRAC* (or any other measure of production efficiency) from available accounting data.

$$EOS \text{ exists if } \frac{\partial C/\partial q}{C/q} = \frac{LRMC}{LRAC} < 1 \tag{7}$$

EOS can be thought of as an elasticity: it measures the change in costs from a one-unit change in output under the assumption that firms are optimizing their efficiency at every point along the production frontier. Intuitively, *EOS* exists when the ratio of marginal costs to average costs is lower for a firm that has optimized its operations to produce a certain output than that for an otherwise-identical firm that has optimized its operations to produce a slightly smaller quantity of output.

EOS is similar in some ways to our scale efficiency construct. Roughly speaking, *EOS* in equation (7) can be restated in terms of declining $LRAC$ as q increases, and scale efficiencies in equation (6) are expressed in terms of declining *CR* as *R* increases. If p does not vary with q, $\partial CR/\partial R < 0$ corresponds to $\partial LRAC/\partial q < 0$, as $CR = LRAC/p$ from equation (5). The two concepts are less similar when prices vary with q. Another distinction between the two concepts, more subtle, relates to the role of continuous optimization. Scale efficiencies describes the observed behavior of firms as they grow, and does not assume that firms optimize at each point. *EOS*, on the other hand, is based on firms re-optimizing at each output level. It is therefore possible for *EOS* to exist even if $\partial LRAC/\partial q = 0$, because the firm re-optimized as scale increased.

The second related concept is *returns to scale* (*RTS*). The textbook definition of returns to scale (again, from Pindyck and Rubinfeld 2005) is the rate at which output increases as inputs are increased proportionally. In other words, if a factory can produce five units of output for every one unit of input, *RTS* captures the difference in total output from adding an extra unit of input. If total production increases to 10 units of output when a second unit of input is added, then the ratio of outputs to inputs is constant and the firm is said to have constant *RTS*. If total production is more (less) than double when inputs double, the firm is said to have increasing (decreasing) *RTS*.

For the Cobb-Douglas production function introduced earlier, increasing/constant/decreasing RTS is indicated by values of $\theta (= \alpha + \beta)$ that are >/=/< than 1.

RTS differs from *EOS* in that the former is based on units of inputs and outputs, whereas the latter is based on costs of input per unit of output. Also, *RTS* does not require firms to re-optimize their production inputs as they scale. As such, the existence of *EOS* does not necessarily imply increasing *RTS*. For example, a firm with constant *RTS* may be able to re-optimize its production inputs as it grows such that it achieves *EOS*. However, if a firm has increasing *RTS*, this suggests that it also has economies of scale.

Equation (4) shows the relation between *LRAC* and *RTS* for the Cobb-Douglas case. Ceteris paribus, *LRAC* increases (decreases) when output increases if $\theta < 1$ (> 1). In the case of constant returns to scale ($\theta = 1$), q drops out and *LRAC* remains unchanged as q increases.

To relate *RTS* to *CR*, we combine equations (4) and (5) to state *CR* in terms of production function parameters.

$$CR = \frac{LRAC}{p} = \frac{\theta . r^{\frac{\alpha}{\theta}} . w^{\frac{\beta}{\theta}} . q^{\frac{1-\theta}{\theta}}}{p(A\alpha^{\alpha}\beta^{\beta})^{\frac{1}{\theta}}} \tag{8}$$

If p is constant, *LRAC* and *CR* behave similarly. If so, the relation between *LRAC* and *RTS* discussed above is transferred to a similar relation between *CR* and *RTS*. That is, increasing (decreasing) *RTS*, indicated by $\theta > 1$ (<1), implies that *CR* decreases (increases) as q increases which in turn implies the presence (absence) of scale efficiencies.

The final economic concept that is related to scale efficiency is total factor productivity (*TFP*), which measures the extent to which a firm is productive at turning inputs into outputs *above and beyond* its ability to re-optimize its input mix as it changes scale. For example, if two firms are the same size and use the same (optimized) inputs, but one firm produces more output than the other, then it has a higher TFP. In the Cobb-Douglas function, TFP is represented by A in the relation $q = AK^{\alpha}L^{\beta}$. Rearranging this formula yields $A = q \,/\, K^{\alpha}L^{\beta}$. In other words, TFP is just the ratio of output to (optimized) inputs. As A is in the denominator in equation (8) above, both CR and $LRAC$ decrease with A. Therefore, scale efficiencies are expected only if TFP increases with scale, ceteris paribus.

To review, scale efficiency is related most closely to EOS, less so with RTS, and most weakly with TFP. Despite the weak relation expected between scale efficiency and TFP, some of the scale efficiencies observed may indeed be due to TFP increasing with scale. Given limitations of available data, we are unable to identify the separate contributions of scale and productivity. As such, we believe that all three economic concepts discussed above could play a role in explaining any scale efficiencies we document.

2.3 Relevant literature

Vast literatures exist in the economics and finance literature on economies of scale, returns to scale, and TFP. Rather than review each of these literatures in detail, we offer a brief summary of the key takeaways from each literature that are relevant for this study.

As it is generally difficult to obtain quantities of output at the firm-level (and convert different products to equivalent units), most of the attempts to measure economies of scale have used establishment-level (i.e. plant-level) data or have focused on specific industries with meaningful data on production quantities. In the first attempt to use large-scale micro-level data to address economies of scale, Griliches and Ringstad (1971) used detailed establishment-level data from the Norwegian census and found strong evidence of economies of scale for manufacturing firms. Other studies have focused on specific industries or specific countries to estimate economies of scale. For example, Christensen and Greene (1976) modelled the cost function of the U.S. electric power industry using output levels and factor prices and found significant evidence of economies of scale. Similar approaches have been applied to other industries (see, e.g., Caves, Laurits, Christensen and Tretheway (1984), who focus on airlines). Another approach uses cross-country data combined with substitution restrictions to identify economies of scale (e.g., Deaton and Paxson 1998). The main takeaway from the literature on economies of scale is that, while they are extremely difficult to measure, economies of scale do in fact appear to exist using detailed plant-level data and within certain industries.[7] However, to our knowledge, there is very little large-sample evidence on the existence of economies of scale at the level of the firm.

A second literature, examining returns to scale, has also provided little evidence at the firm level. Early attempts such as Nerlove (1963) estimated increasing returns to scale for specific industries (such as electricity) using simple Cobb-Douglas-style production functions. Macroeconomists have also studied returns to scale at the national and international level, with mixed results (see, e.g., Jones (1995), Easterly and Levine (2001). Large-sample microeconomic evidence on the existence of returns to scale at the firm level also paints a mixed picture. For example, Basu and Fernald (1997) and Klette (1999) estimate returns to scale using large-sample manufacturing data from the U.S. and Norway (respectively) and find constant or decreasing returns to scale in most industries, which Basu and Fernald (1997) blame on the common aggregation practice of treating an industry as if it were a firm. In contrast, Hall (1988, 1990) finds little evidence of decreasing returns to scale across a study of seven broad industries and 26 detailed industries. Moreover, micro-level investigations using detailed establishment-level data

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[7] In contrast, Scherer, Beckenstein, Kaufer, and Murphy (1975) find that the effect of operating at an inefficient scale typically has a negligible effect on long-run unit costs.

has consistently found evidence of constant or increasing returns to scale (see, e.g., Griliches and Ringstad (1971), Lee (2007)).

A large literature also exists on total factor productivity. This microeconomic literature on *TFP* is summarized in survey papers by Bartelsman and Doms (2000) and Syverson (2011).[8] As with the literatures on economies of scale and returns to scale, TFP studies in the microeconomics literature have also gravitated towards the use of very granular data. For example, many recent studies use establishment-level data from various national Census estimates to estimate *TFP*. Moreover, these studies have primarily focused on understanding *differences* in *TFP* across establishments rather than in measuring aggregate *TFP* levels and aggregate *TFP* growth over time. Similarly, a separate literature in macroeconomics has examined *TFP* differences across countries and across industries within a given country. For example, Domowitz, Hubbard, and Petersen (1988) and Jorgenson and Stiroh (2000) decompose U.S. *TFP* growth by industry and find large average differences across industries (which the latter paper argues are not due to industry concentration), while Edwards (1998) finds that *TFP* growth is faster among countries with relatively open trade policies. However, while the literature on *TFP* has been primarily focused on understanding *TFP* differences across establishments, industries, and countries, the literature is unanimous that economy-wide *growth* in *TFP* has been positive in the U.S. dating back to the beginning of the post-war era.

Our paper differs in at least four respects from the papers in the aforementioned literatures. First, our primary focus is on costs per dollar of revenue rather than the costs per unit relevant for economies of scale, and we also consider non-manufacturing and financing costs that are not

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[8] As noted by Syverson (2011), most researchers focus on revenue-based proxies for output in studies of productivity or scale efficiencies, even in cases where more detailed establishment-level data is available. In particular, since researchers are typically concerned with variation in these proxies (as opposed to levels), any general problems induced by measurement error are likely to be dwarfed by "valid" economic variation across firms.

typically considered in those literatures. Second, we focus on overall efficiencies, rather than focus on one of the separate components, such as changes in productivity, production functions, and prices,. Third, our unit of analysis is the firm, rather than the plant, the industry, or the economy as a whole. Finally, our goal is to characterize the evolution of costs over time at the same firm, without making assumptions about the level of optimization, rather than to examine scale or productivity differences across firms operating at long-run optimum levels.

A related literature in finance and economics has used changes in firm boundaries (such as mergers or acquisitions) to evaluate economies of scale and production efficiency. Papers using accounting data generally find that operating performance improves at the combined firm following mergers, though these papers cannot distinguish between scale and productivity improvements (Healy, Palepu, and Ruback (1992); Andrade, Mitchell, and Stafford (2001)). A second strand of the literature looks at market power and supplier power and generally finds evidence that following mergers, the combined firm's increased scale allows it to extract more rents from customers and suppliers (Kim and Singal (1993), Focarelli and Panetta (2003), Fee and Thomas (2004), Shahrur (2005), Ashenfelter amd Hosken (2010), Bhattacharya and Nain (2011)). Scale has also been shown to help merged firms reduce operating costs (Hoberg and Phillips (2010), Fee, Hadlock, and Pierce (2012)). However, the literature has also found evidence of significant production efficiencies. Using data from *Consumer Reports*, Sheen (2014) find that prices fall and quality perceptions of the combined firm's goods rise following mergers. Using establishment-level Census data, Maksimovic and Phillips (2001) and Maksimovic, Phillips, and Prabhala (2013) find that high-productivity firms buy low-productivity firms whose production efficiency subsequently improves following takeovers. Hence, they find that the combined firms' total TFP rises following acquisitions. Schoar (2002) finds that these effects do not always hold when conglomerates make diversifying acquisitions. The literature on mergers and acquisitions finds strong evidence consistent with the broader literature's findings on scale and production efficiencies in a number of different contexts.

2.4 Measuring CR

We use financial data to estimate the ratio of costs to sales for four cost categories, as described in Table 1. We consider production costs, referred to as costs of goods sold (*COGS*), and other operating costs, referred to as selling, general, and administrative costs (*SG&A*). We strip out depreciation and amortization (*D&A*) from operating costs to separately consider the costs of capital expenditures. We do not consider tax costs, which are a product of pre-tax income and tax rates. Pre-tax income has already been considered in the cost ratios mentioned above. And we wish to exclude the effects of time-series variation in tax rates because they are unrelated to economies of scale.

The costs of financing are represented by interest costs for debt financing and required profit for equity financing. They are computed as the product of the required rate of return times the book value of investment for each investor type. There is considerable time-series variation in nominal required rates of return, mainly due to variation in expected inflation. We assume that variation is unrelated to scale efficiencies and absorb it in year fixed effects. We do not estimate asset risk and assume that it remains constant over time for each firm. In effect, rather than measure financing costs/sales, we focus on the (book value of debt + equity)/sales.[9] Given that scale efficiencies are associated with operations not cash balances, we deduct cash from the book values

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[9] We provide additional results that attempt to control directly for the costs of financing. Reported interest expense proxies for the cost of debt and the book value of equity times an imputed costs of equity (= the 30-year risk-free rate + an equity premium of 3 percent) proxies for the cost of equity.

of debt plus equity. This cash-adjusted ratio can also be stated as the ratio of net operating assets (*NOA*) to sales, where *NOA* is operating assets less operating liabilities.

If scale efficiencies exist, all four components of *CR*—*COGS/Sales*, *SG&A/Sales*, *D&A/Sales*, and *NOA/Sales*—should decline as scale increases. Note that *NOA/Sales* is related to the concept of asset "productivity" measured by asset turnover (Sales/Assets). If scale efficiencies cause *NOA/Sales* to decline with scale, they should also cause asset turnover to increase with scale.

We also consider three measures of profit described in Table 1. *EBIT* represents the sum of operating income—which considers the *COGS*, *SG&A*, and *D&A*—and non-operating income. *NI*, or GAAP income, which equals *EBIT* minus taxes and interest, deducts all costs from revenue except the cost of equity. *EI* represents economic income, which deducts the cost of equity too.

We track firms as they grow to observe the extent to which average costs/revenues decline and profits/revenues increase. We recognize that growth in scale is not randomly assigned. In particular, growth in scale is likely to be positively related to anticipated scale efficiencies: firms expecting larger increases in profit margins for reasons other than scale efficiencies are likely to grow faster. To mitigate against a mechanical relation between growth and scale efficiencies, we use firm age (*AGE*) as an instrument for scale.[10] That is, scale efficiencies exist if

$$\frac{\partial CR}{\partial AGE} < 0 \text{ and } \frac{\partial PM}{\partial AGE} > 0\,. \tag{9}$$

3. Methodology, sample, and descriptive statistics

3.1. Methodology

Our methodology is straightforward: we measure the extent to which the different measures of costs/sales (*CR*) decline and profits/sales (*PM*) increase with *AGE*, and attribute this decline to

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[10] We confirm that our sample firms grow substantially, on average, as they age.

scale efficiencies. Our primary investigation focuses on a sample of IPO firms. By examining all available data on such firms we are able to document efficiencies at different life-cycle stages. Firm fixed effects control for variation in *CR* and *PM* across firms because of firm-specific factors and choices, and year fixed effects control for variation over time in economy-wide factors, such as the changes in expected inflation discussed earlier.

While much growth arises organically because of internal investments, it can also occur via acquisitions of other firms. Discussions of synergies associated with acquisitions mention scale efficiencies prominently. Large acquisitions present an opportunity to identify scale efficiencies because of the significant and abrupt changes in scale that ensue. However, these changes in scale are again not exogenous. Bidders and targets may seek to merge because of anticipated changes in profitability. We compare changes in the components of *CR* and *PM* around acquisitions (for bidders and targets combined) with corresponding changes for size -matched control firms from the same 4-digit SIC industry that did not grow through acquisitions in that year.

We conduct additional analyses designed to confirm the robustness of these results. We consider other samples that include public non-IPO US firms, public non-US firms, private firms in Europe, and estimate Cobb-Douglas functions to see if productivity or returns to scale vary with *AGE*.

3.2. Samples

Our primary analyses focus on growth in the two samples mentioned above: IPO firms and acquisitions (M&A). Table 2 Panel A describes the observations deleted at each stage as we collect the IPO sample. We begin with all firm-year observations between 1950 and 2014 from the Compustat/CRSP merged universe. We remove from this sample firms in industries that relate to financial services and utilities, as well as observations with missing variables of interest, and firms with assets or annual sales less than $10 million in 2014 dollars.[11] We return to this intermediate CRSP/Compustat sample, containing 109,662 firm-years, for robustness analyses in Section 5.

Merging the intermediate sample with IPO data from Professor Jay Ritter's web site yields 4,756 distinct IPOs.[12] The resulting Ritter IPO sample contains 37,132 firm-years between 1976 and 2014. (Because the change in *NOA* variable requires two prior years of *NOA* data, we lose the first two observations in each series.) Table 3, Panel A describes the distribution of observations across industry membership and *AGE.* Industry membership refers to 7 broad sectors as defined by the GICS classification and the different *AGE* cohorts are based on years since the firm was incorporated. Later we consider an alternative measure of *AGE*, based on years since the IPO.

Table 2, Panel B describes the process followed to collect our M&A sample. We begin with deals included in the SDC database, and restrict our attention to deals that took place between 1980 and 2010 between US, publicly-traded acquirers and targets from non-financial industries. We cut off our sample at 2010 to ensure sufficient data on post-acquisition performance. We also require that both the acquirer and target have reliable CUSIP links to CRSP/Compustat as well as information on pre-deal company performance. These restrictions result in 2,054 distinct deals.

For the robustness analyses described in Section 5, we consider two additional samples. First, we supplement the results obtained for public US firms with a global sample of public companies from FACTSET. This database provides financial information and date of incorporation for both US and non-US firms from around the world. We delete financial services firms (1-digit SSIC=6); firm-years with missing profit margin information and sales less than $10mm (adjusted for inflation and exchange rates to 2014 U.S. dollars); and countries with fewer

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[11] For purposes of comparison, this filter corresponds to $1 million in 1950 dollars.

[12] IPO dates and AGE since incorporation is obtained from. https://site.warrington.ufl.edu/ritter/ipo-data/

than 1,000 firm-years with available data. This sample contains 366,355 observations spanning 1990 to 2014.

Second, we supplement the results obtained for public firms with a sample of private European firms from Bureau van Dijk's AMADEUS database. We use editions of this database released between 2003 and 2013 to obtain financial information and date of incorporation. Again, we delete financial services firms (1-digit SSIC=6); firm-years with missing profit margin information; and countries with fewer than 1,000 firm-years with available data. This sample contains 1,684,189 firm-years. For all samples mentioned above, we Winsorize continuous variables at the 1st and 99th percentiles of their distributions.

3.3. Descriptive statistics

Table 4, Panel A provides distributional statistics relating to variables for our IPO sample. These variables (see Appendix A for details) are mainly ratios reflecting measures of costs and profits, expressed as a percentage of Sales. The left half describes levels and the right half describes first-differences or changes. Median (p50) levels reported for the first three rows suggest that *COGS*, *SG&A* and *D&A* are about 60, 29 and 4 percent of sales, leaving about 7 percent in pre-tax operating profit for a representative firm-year. Median *EBIT* is about 6 percent of sales, reflecting the effect of non-operating items. Non-cash operating assets, reported in the fourth row, multiplied by the pre-tax cost of debt and equity reflects the pre-tax cost of capital. If the pre-tax cost of capital is roughly 10 percent, ignoring for now any time-series and cross-sectional variation, median financing costs are about 5 percent of sales. Median *NI*, which deducts all costs including taxes but not the cost of equity, is about 3 percent of sales. Deducting a cost of equity, equal to the 10-year Treasury bond yield plus a risk premium of 3 percent for all firms, leaves a small negative median *EI*.

The next three rows describe Market-to-book (*M/B*) ratios, and *AGE* based both on the years that the firm has data on CRSP (since IPO) and the years since incorporation. Median values of the three variables are about 2, 8 years, and 20 years. The last row in Table 4, Panel A describes relative scale, which is the ratio of inflation-adjusted sales in that firm-year deflated by inflation-adjusted sales in the first post-IPO year. Those results suggest considerable real growth after the IPO date for most firms, and a median of 2.5 across all firm-years. Observing high levels of growth provides support for our use of *AGE* as an instrument for scale.

The results reported for changes in the right half of Table 4, Panel A provide a simple analysis of scale efficiencies. Changes in cost measures in the first four rows should on average be negative if growth is associated with efficiencies. Not only do we observe positive median values for three of the four cost measures, the magnitudes of the changes seem very small in magnitude. (Recall that the change in *NOA* needs to be multiplied by the pre-tax cost of capital.) Whereas the changes in profit measures in the next four rows are all positive, consistent with scale efficiencies, the magnitudes again appear quite small.

Figure 1 offers a picture of how median changes in the different cost and profit measures vary across *AGE* cohorts and industry sectors. These plots allow us to identify potential variation across industry (e.g., scale efficiencies are observed in some but not all industries) and non-linearities as *AGE* varies (e.g., scale efficiencies are higher for young firms, soon after IPO, but decline as firms mature). Under scale efficiencies, the changes for cost measures should lie below zero and changes for profit measures should lie above zero. In general, there is little systematic evidence in Figure 1 of scale efficiencies, with two exceptions. First, unlike the other cost measures, changes in median SG&A/Sales appear to be negative for more industries. Second, Health care consistently exhibits negative median changes for cost measures and positive median changes for profit measures, especially for low levels of *AGE*.

4. Main results

4.1. Ritter IPO sample

We turn from investigating changes in cost and profit measures to regressing levels of those measures on *AGE*. If efficiencies increase as firms grow, we expect negative (positive) coefficient estimates on *AGE* for cost (profit) measures. Our results are reported in Table 5, with Panels A and B corresponding to regression specifications that exclude and include three control variables that affect cost and profit measures: lagged values of total assets, book leverage, and *M/B* ratios. All specifications include year and firm fixed effects to control for time-series and cross-sectional variation due to omitted variables.

The results in Panel A of Table 5 confirm the general tenor of the initial findings reported in Table 4 and Figure 1: there is little evidence of scale efficiencies. All the coefficient estimates on *AGE* are insignificant. The signs of the coefficient estimate suggest that efficiencies decline, rather than increase, as firms grow: the coefficient on *AGE* for cost measures is generally positive and that for profit measures is generally negative. Estimates for the constant in each specification, which reflects average firm fixed effects, is consistent with the means reported in Table 4 for the corresponding levels of the dependent variables.

Including control variables in Panel B does not alter the main conclusion. Before discussing the results, we note that these control variables are not exogenous. While they explain firm performance, they could be dependent variables in other specifications that are explained by firm performance. Our motivation to include them without building a more general model of interaction among these variables, is to document the impact of including them. Our results suggest that even though the controls are associated with very significant coefficient estimates, the coefficient estimates on *AGE* are relatively unaffected. Except for the coefficient on D&A, which is negative and significant at the 10 percent level, all other coefficient estimates for cost and profit measures remain insignificant.

To investigate potential non-linearities in the relation between performance measures and *AGE*, we repeat the analysis in Table 5 for the subset of observations with *AGE* less than 10 years. If scale efficiencies are more evident in the initial years after they go public, the coefficients on *AGE* should be more significant for this subsample. Our results, reported in Table 6, are inconsistent with this proposition. We find two coefficient estimates in Panel A that are significant at the 10 percent level, when control variables are excluded: While the coefficient for *D&A* is negative, consistent with scale efficiencies, the coefficient for *COGS* is positive. In Panel B, when control variables are included, the only significant coefficient on AGE that we observe is again observed for *D&A*. We conclude that except for this evidence consistent with depreciation and amortization not growing as fast as sales for "young" IPO firms, all other measures of performance suggest no significant evidence of performance improvement as IPO firms age.

4.2. M&A sample

Despite the large size of our IPO sample, it is possible that our methodology lacks statistical power. That is, scale efficiencies exist but our weak tests are unable to reject the null hypothesis. We turn to another arena—when one firm acquires another—where scale efficiencies have been documented in the prior literature. The combined changes in value, for acquirers and targets, representing the synergies associated with the deal are in general positive in these transactions. And the synergies associated with these deals are often stated in terms of scale efficiencies: merging eliminates redundancies in corporate functions, such as information technology and distribution. The redundancies arise because these function are claimed to have relatively fixed costs; i.e., scale can be doubled without doubling costs.[13]

We compare the change in cost and profit measures around acquisitions with changes for control, non-acquiring firms in the same industry, matched on size. Table 7 provides the results of those comparisons. Panel A compares changes between the year before the acquisition (t-1) to two years after the acquisition (t+2), where the year of acquisition is year t. Panel B takes a longer perspective and moves the post-acquisition year investigated from two to five years after the acquisition (t+5). The top half in each panel describes mean growth whereas the bottom half describes median growth. The first two rows in each half report growth for the treatment (acquirer + target) and control firms, respectively. The third row reports the difference between the treatment and control firm in each matched pair and the fourth row provides a p-value associated with that difference.

The results for medians are also provided in Figure 2. Statistical significance based on p-values reported in Table 7 are also provided, based on the usual conventions: One/two/three stars for results that are significant at the 10/5/1 percent level. Differences between treatment and control groups that are in the direction predicted by scale efficiencies are shown in green, whereas those in the opposite direction are in red and placed in parentheses.

The results in Table 7 and Figure 2 find significant performance improvements around acquisitions. The results are strongest for median growth from t-1 to t+2. Moving from medians to means and moving from t+2 to t+5 reduces the number of instances where changes in cost and profit measures are significant and of the right sign. Note the relatively small magnitudes of the

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[13] Value is sometimes generated in acquisitions by operating one of the entities more efficiently. Even though such performance improvements are unrelated to scale efficiencies, they are relevant for this investigation because our objective is to show that performance improvements can be detected when they exist.

matched pair differences observed for the cases where the medians indicate significant performance improvement. That is, our methodology identifies performance improvements when they exist, even if they are relatively small in magnitude. Not only are these performance improvements consistent with those reported in the prior M&A literature, they indicate that our methodology is associated with reasonable levels of statistical power.

5. Robustness analyses

This section provides the results of several analyses conducted to confirm that our inferences from Section 4 are robust. We repeat the Table 6 regressions of cost and profit measures on *AGE* for three other samples: a) the intermediate CRSP/Compustat sample, described in Table 2, which includes public US firms not in the Ritter IPO sample; b) the FACTSET global sample, which contains publicly-traded US and non-US firms; and c) the AMADEUS sample, which contains private European firms. All three samples are much larger than our IPO sample, but the CRSP/Compustat sample is associated with more noisy measures of AGE, and the two other samples provide data on fewer measures of performance.

The results reported in Table 8 for regressions estimated on the CRSP/Compustat sample, with 109, 662 firm-years, are consistent with the results observed for the IPO sample.[14] *AGE* is measured by the number of years the firm has data on CRSP, as the date of incorporation is not available for this sample. This variable measures *AGE* since incorporation with error. The coefficient on *AGE* in the Panel A regressions (without control variables) suggests no evidence of scale efficiencies. The only significant coefficient observed is for *EBIT*, but it is of the wrong sign. Moving to the results in Panel B, which include control variables, we note significant coefficient estimates on *AGE* for two cost measures (*D&A* and *NOA*) and two profit measures (*NI* and *EI*). As

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[14] Descriptive statistics for the CRSP/Compustat sample are provided in Panel B of Table 4.

with the results in Panel B of Table 6, we are uncertain about how to interpret the results obtained with control variables because of potential endogeneity associated with those variables.

Observing insignificant coefficients on *AGE* for the two samples of US public firms suggests that the future levels of costs and profits can be simply forecasted assuming that the measures follow a random walk with no drift. To get a sense of the accuracy of those predictions we compute forecast errors for levels of the different cost and profit variables and report the distribution of forecast errors as a percent of sales. Those results are reported as Box plots in Panel A of Figure 3, with the whisker-ends corresponding to the 10th and 90th percentiles of the distribution. We also report in Panel B the distribution of forecast errors, scaled by actual values of the forecasted variable. Because the profit variables are on occasion negative or very small, we only report results for the four cost variables. The overall picture that emerges from Figure 3 is that the cost measures are remarkably "sticky" and are reasonably well predicted by last year's values. The profit measures are harder to predict, however.

Panels A and B of Table 9 contain the results of estimating regressions of profit measures on *AGE* for the AMADEUS and FACTSET samples, respectively. We are unable to obtain data on our cost measures for both samples, and gross profits were missing for most observations in the AMADEUS sample. Whereas our results so far indicate insignificant coefficient estimates on AGE, for these samples the coefficients are all *negative*, and significant for all profit measures except *NI*. Scale efficiencies appear to be negative, not zero, for private European firms and public non-US firms.

Although we are unable to obtain data for our cost measures for these two samples, we located variables that are related to NOA. AMADEUS provides Net Asset Margin (=Shareholders' equity + long-term liabilities, scaled by sales), and FACTSET provides Asset Margin

(= Sales/Total Assets). The coefficient on *AGE* for Net Asset Margin is negative, consistent with positive scale efficiencies, but inconsistent with the profit measure results in Table 9, Panel A. The coefficient for Asset Margin is significantly negative, consistent with the negative scale efficiencies observed for the profit measure results in Table 9, Panel B.

Estimating these regressions within countries for the two samples produces results consistent with the inferences from the full-sample results reported in Table 9. For the AMADEUS sample, most of the coefficients for profit measures are negative and 11 of the 12 significant estimates are negative. For the FACTSET sample, again most of the coefficients for profit measures are negative and 26 of the 34 significant estimates are negative.

Our final robustness analysis is based on estimating Cobb-Douglas functions on our IPO and CRSP/Compustat samples. The natural log of sales is regressed on natural logs of number of employees, net fixed plant, and capitalized R&D. The constant in this regression is total factor productivity (TFP) and the sum of the coefficients on the three inputs reflects return to scale (RTS). Our objective is to determine if TFP and RTS increase as firms grow. Given that scale efficiencies are not observed for these samples, we expect that both TFP and RTS are likely to also remain relatively constant with *AGE*.

We begin with an exploratory analysis, and estimate the production function within each year for the CRSP/Compustat sample. We include industry sector fixed effects. The coefficient on employees is the largest and relatively constant, the coefficient on fixed assets declines early in the sample period, and the R&D coefficient increases steadily over time. We find that RTS, the sum of the exponents, is remarkably close to 1, and is insignificantly different from 1 after 1998.

Table 10, Panel A provides estimates of the production function coefficients for the pooled CRSP/Compustat sample as well as within each of the industry sectors. We include firm fixed effects in all the regressions. While we observe some variation in RTS and TFP across industry sectors, our main finding is that the estimate for TFP is considerably lower than the level of 1 reported in Figure 4. We find this lower estimate for TFP is due to the introduction of firm fixed effects.

Panel B of Table 10 provides coefficient estimates when the production function is estimated within different *AGE* cohorts for the CRSP/Compustat (left half) and IPO (right half) samples. We include firm and industry-year fixed effects. The magnitudes of the coefficients are similar to those reported for the overall sample in the first column of Panel A. More relevant to our study, we do not find a clear pattern of RTS and TFP increasing with *AGE*.

In sum, the analyses reported in this section suggest that the findings from our IPO sample are robust. For public US firms there is little evidence of scale efficiencies. For non-US firms, both public and private, the evidence is again inconsistent with scale efficiencies. In fact, there is evidence of negative scale efficiencies for these samples.

6. Concluding thoughts

It is common for business analyses and projections to assume that the ratio of costs/sales for different cost items declines as firms grow. Justification for scale efficiencies is provided by the notion that some costs stay relatively fixed, even in the long-run, and increase scale is associated with increased bargaining power. Relatedly, there is a concern that firm decisions are distorted because users of resources are charged for average costs, rather than marginal costs.

Even though this assumption of declining costs/sales is common wisdom, almost a self-evident truth, there is little empirical evidence documenting the magnitude of scale economies. While the economics literature has investigated related concepts, such as economies of scale and returns to scale, these studies have not examined the evolution of costs/sales at the firm-level.

We conduct a comprehensive analysis of scale efficiencies for different cost items across different samples. Our main analysis tracks firms as they grow from their IPO date. Our results are surprising because we see little evidence of scale economies. In general, costs/sales ratios remain flat (increase slightly for non-US firms) for different costs and samples. Additional probing of this result suggest that it is robust.

The most direct interpretation of our results is that they reflect the underlying nature of how costs evolve as firms grow; i.e., costs/sales do not on average decline with growth. But our evidence is also consistent with alternative explanations, some of which are as follows. First, the representative firm in our samples operates in competitive product markets and long-run average costs equal selling prices. If so, any gains that arise from scale efficiencies as firms grow are passed on to the consumer. Second, observing no scale efficiencies is an artifact of the budgeting process: firms allocate resources to different groups based on the corresponding historical relationship with sales. Any scale efficiencies that arise are spent, to avoid cuts in next year's allocation. This explanation predicts that organizations using "zero-based" budgeting are more likely to experience scale efficiencies.

Regardless of why our results are observed, the empirical regularity we document has important implications. First, projections that routinely anticipate declining average costs are likely optimistic. Any scale efficiencies projected, especially if they are based on short-run marginal costs, deserve careful scrutiny to confirm that they are reasonable and supported by experience. More generally, the teaching of concepts based on short-run cost behavior—fixed/variable costs, contribution margins, and breakeven analysis—should be tempered by evidence on patterns observed for long-run average costs/sales. Second, if long-run average costs are close to long-run marginal costs, charging users for the average costs of resources does not distort behavior and decisions. Finally, individual line items of costs can reasonably be predicted by multiplying projected sales by recently observed ratios of cost/sales.

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Appendix A
Variable Definitions.

Variable Name	Compustat Definition
Cost of Goods Sold	COGS / SALE
Selling, General & Admin. Expenses	XSGA / SALE
Depreciation & Amortization Expense	DP / SALE
Eearnings before Depr. Interest & Tax	OIBDP / SALE
Eearnings before Interest & Tax	OIADP / SALE
Net income	IB / SALE
Economic Income[a,b]	[IB – (0.03 + 10-year T-bond rate) × SEQ] / SALE
Net Operating Assets[b]	[AT – CHE – (LCT – DLC) – (LT – LCT – DLTT)] / SALE
Sales	SALE
Assets	AT
Market-to-book Ratio	(PRCC_F × CSHO) / SEQ
Leverage	(DLC + DLTT) / AT
Relative scale[a]	$(SALE_t / CPI_t) / (SALE_0 / CPI_0)$

Notes:

[a] Government bond rates and CPI (Consumer price index) are from Global Financial Data.

[b] Averages of current and lagged fiscal year values are used for book value of equity when computing economic income and Net Operating Assets/Sales

Table 1
Cost and profit ratios investigated

Recast Income Statement into cost and profit measures

Item	Measure investigated
Sales	
Less: Production costs (excluding depreciation & amortization)	COGS/Sales
= Gross profit	Gross Profit/Sales
Less: Other operating costs (excluding depreciation & amortization)	SG&A/Sales
Less: Depreciation and Amortization	D&A/Sales
= Operating profit	
Plus/minus Non-operating items	
= Earnings before interest and tax or EBIT	EBIT/Sales
Less: Interest expense (= cost of debt * book value of debt)	Included in NOA/Sales[1]
= Pre-tax income	
Less: Tax expense	Not considered[2]
= Net Income	NI/Sales
Less: required profit on equity (= cost of equity * book value of equity)	Included in NOA/Sales[1]
= Economic or abnormal profit[3]	EI/Sales

Notes:
1. The costs of debt and equity financing equal the required rate of return * book value for both items. We assume that variation in required rates of return for debt and equity are unrelated to scale efficiencies and focus on the book values of debt and equity, net of cash, which represent net operating assets (operating assets less operating liabilities) or NOA.
2. We ignore tax costs, which equal profits * tax rate, because profits are already considered in the cost measures, and variation in tax rates is unrelated to scale efficiencies.
3. This row and the one above are not provided in GAAP Income Statements.

Table 2.
Sample Selection

Panel A: Selection of Ritter IPO sample.

Step	# Remaining Observations
Compustat-CRSP Merged Fundamentals Annual (1950–2014)	242,613
*Less:*Financial sector and utility industry groups	178,108
*Less:*Obs. with missing control variables or variables of interest	118,584
*Less:*Obs. with negative equity, or real assets or sales less than $10mm (in 2014 dollars)	109,662
==> Final CRSP/Compustat Sample	109,662
*Less:*Obs. with missing IPO dates (as reported in Jay Ritter's website)	37,132
==> Final Ritter Sample	37,132

Panel B: Selection of M&A sample

Step	# Remaining Observations
US public, non-financial acquirer; US public, non-financial target (1980–2010) *(completed deals)*	4,463
Less: Obs. with both parties cannot be linked to Compustat/CRSP universe	3,033
*Less:*Obs. with missing future growth variables	2,054
==> Final M&A Sample	2,054

Table 3: Sample composition: industry membership and AGE

Panel A: Ritter IPO sample

	Number of observations: Grand total is 37,132 firm-years					
Age since incorp.	<10	≥10 & <20	≥20 & <30	≥30 & <40	≥40	TOTAL
Industries (GICS groups):						
Energy (10)	241	477	425	174	372	1,689
Materials (15)	173	318	281	219	419	1,410
Industrials (20)	567	1,344	1,075	546	1,422	4,954
Consum. Dscrtnry (25)	1,024	2,274	1,717	1,028	2,297	8,340
Consumer Staples (30)	164	435	325	202	556	1,682
Health Care (35)	909	2,330	1,505	544	290	5,578
Infor. Technology (45)	2,078	5,875	3,315	1,279	705	13,252
TOTAL	5,156	13,053	8,643	3,992	6,061	36,905

Panel B: Compustat/CRSP sample.

	Number of observations: Grand total is 109,662 firm-years					
CRSP Age Bucket	<10	≥10 & <20	≥20 & <30	≥30 & <40	≥40	TOTAL
Industries (GICS groups):						
Energy (10)	2,580	1,666	835	418	741	6,240
Materials (15)	3,105	2,558	1,418	905	1,737	9,723
Industrials (20)	7,107	5,893	3,221	1,815	2,342	20,378
Consum. Dscrtnry (25)	10,222	6,908	2,979	1,336	1,869	23,314
Consumer Staples (30)	2,732	2,211	1,183	702	1,433	8,261
Health Care (35)	4,927	3,341	1,197	456	504	10,425
Infor. Technology (45)	11,346	6,661	2,349	794	598	21,748
TOTAL	42,019	29,238	13,182	6,426	9,224	100,089

Notes:
CRSP Age equals the number of prior years with data on CRSP as of that firm-year.

Table 4. Descriptive Statistics

Panel A: Ritter IPO Sample (37,132 firm-years)

Item	Levels					Changes				
	Mean	St. dev.	p10	p50	p90	Mean	St. dev.	p10	p50	p90
Cost of goods sold (% sales)	57.61	20.90	26.70	60.13	83.34	0.18	6.34	-5.03	0.07	5.73
SG&A expenses (% sales)	34.49	25.63	8.42	28.89	66.47	-0.56	10.52	-7.02	-0.05	6.30
D&A expenses (% sales)	5.73	6.83	1.43	3.89	10.84	-0.01	3.57	-1.60	0.04	1.68
Non-cash net op. assets or NOA (% sales)	61.41	55.78	16.52	47.49	116.56	0.40	23.93	-16.45	0.21	18.40
EBIT (% sales)	1.85	23.73	-16.06	5.64	19.45	0.48	16.52	-10.61	0.08	10.26
Net profit or NI (% sales)	-3.45	29.98	-22.42	2.72	13.27	0.32	26.85	-14.08	0.02	13.83
Economic profit or EI (% sales)	-8.97	32.94	-29.77	-0.55	7.52	0.73	28.30	-14.38	0.07	15.07
Market-to-book or M/B ratio (%)	286.85	303.60	74.46	196.58	575.79	-11.69	240.51	-185.22	-5.19	154.15
Age (CRSP)	9.49	6.35	2.83	7.76	18.70					
Age (incorporation)	26.57	22.52	8.00	20.00	55.00					
Relative scale	12.84	50.35	0.89	2.46	17.92					

Panel B: CRSP/Compustat Sample (109,662 firm-years)

Item	Levels					Changes				
	Mean	St. dev.	p10	p50	p90	Mean	St. dev.	p10	p50	p90
Cost of goods sold (% sales)	63.71	18.35	37.04	67.08	84.40	0.14	5.58	-4.30	0.00	4.74
SG&A expenses (% sales)	26.07	20.08	7.36	21.36	49.15	-0.19	7.41	-3.80	0.02	3.89
D&A expenses (% sales)	4.88	6.09	1.19	3.20	9.16	0.03	2.56	-1.04	0.03	1.17
Non-cash net op. assets or NOA (% sales)	60.88	53.24	19.40	47.68	110.35	0.33	20.73	-13.45	0.04	14.83
EBIT (% sales)	5.07	17.49	-5.53	6.80	18.04	0.07	12.22	-6.99	0.04	6.21
Net profit or NI (% sales)	0.43	20.69	-9.07	3.42	11.51	-0.02	18.36	-7.97	0.03	6.77
Economic profit or EI (% sales)	-4.58	22.66	-15.50	0.00	5.96	0.16	19.39	-8.26	0.00	7.46
Market-to-book or M/B ratio (%)	228.76	251.78	57.37	156.18	457.12	-6.65	181.23	-124.32	-1.45	105.78
Age (CRSP)	16.59	15.01	3.46	11.62	38.23					
Relative scale	9.78	39.99	0.83	2.24	14.18					

Notes: All continuous variables have been Winsorized at the 1st and 99th percentiles of their distribution.

Table 5
Regressions of cost/sales and profit/sales on AGE since incorporation for Ritter IPO sample

Panel A: Without control variables

	Cost measures (%)				Profit measures (%)		
Dependent Variable	COGS/Sales	SG&A/Sales	D&A/Sales	NOA/Sales	EBIT/Sales	NI/Sales	EI/Sales
Constant	56.705***	26.913***	4.087***	56.246***	12.295***	5.291***	-2.163
(t-statistic)	(25.10)	(11.38)	(7.80)	(8.19)	(6.93)	(4.07)	(-1.53)
AGE (since Incorporation)	0.005	0.108	-0.003	0.224	-0.116	-0.181	-0.137
(t-statistic)	(0.05)	(0.98)	(-0.10)	(0.77)	(-1.59)	(-1.01)	(-0.72)
Observations	37,132	37,640	37,132	37,132	37,132	37,132	37,132
Adj. R-squared	0.868	0.816	0.679	0.713	0.555	0.441	0.462
Year FE	YES	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES

Panel B: With control variables

	Cost measures (%)				Profit measures (%)		
Dependent Variable	COGS/Sales	SG&A/Sales	D&A/Sales	NOA/Sales	EBIT/Sales	NI/Sales	EI/Sales
Constant	60.338***	30.694***	1.301**	14.718**	9.034***	10.964***	5.981**
(t-statistic)	*(23.44)*	*(12.84)*	*(2.23)*	*(2.15)*	*(4.24)*	*(4.18)*	*(2.11)*
AGE (since Incorporation)	-0.027	0.087	-0.043*	-0.305	-0.014	0.005	0.061
(t-statistic)	*(-0.28)*	*(0.81)*	*(-1.93)*	*(-1.41)*	*(-0.22)*	*(0.03)*	*(0.37)*
Ln (lagged total assets)	-0.546**	-0.377	1.467***	19.285***	-1.177**	-5.244***	-6.845***
(t-statistic)	*(-2.41)*	*(-1.26)*	*(10.17)*	*(20.77)*	*(-2.57)*	*(-7.17)*	*(-8.46)*
Ln (lagged leverage)	0.022**	-0.026**	0.006	0.218***	0.011	0.019	0.099***
(t-statistic)	*(2.47)*	*(-2.38)*	*(1.55)*	*(7.09)*	*(0.78)*	*(0.99)*	*(4.61)*
Ln (lagged market-to-book)	-2.215***	-2.231***	-0.854***	-8.350***	5.362***	6.409***	6.955***
(t-statistic)	*(-15.06)*	*(-10.29)*	*(-11.22)*	*(-16.53)*	*(17.84)*	*(15.41)*	*(15.37)*
Observations	37,132	37,132	37,132	37,132	37,132	37,132	37,132
Adj. R-squared	0.872	0.821	0.699	0.759	0.573	0.465	0.490
Year FE	YES	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES

Table 6
Regressions of cost/sales and profit/sales on AGE since IPO for young firms (*AGE* < 10 years) in Ritter IPO sample

Panel A: Without control variables

	Cost measures (%)				Profit measures (%)		
Dependent Variable	COGS/Sales	SG&A/Sales	D&A/Sales	NOA/Sales	EBIT/Sales	NI/Sales	EI/Sales
Constant	55.844***	28.812***	0.710	30.175	14.792***	12.592**	6.508
(t-statistic)	(16.05)	(7.93)	(0.45)	(1.53)	(3.48)	(2.07)	(0.98)
AGE (since IPO)	0.329*	-0.097	-0.179*	-1.106	-0.046	0.355	0.495
(t-statistic)	(1.68)	(-0.44)	(-1.87)	(-0.88)	(-0.19)	(0.94)	(1.20)
Observations	23,032	23,032	23,032	23,032	23,032	23,032	23,032
Adj. R-squared	0.894	0.848	0.681	0.777	0.602	0.472	0.496
Year FE	YES	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES

Panel B: With control variables

	Cost measures (%)				Profit measures (%)		
Dependent Variable	COGS/Sales	SG&A/Sales	D&A/Sales	NOA/Sales	EBIT/Sales	NI/Sales	EI/Sales
Constant	55.886***	29.331***	-2.141	-0.329	18.957***	26.148***	22.369**
(t-statistic)	(15.14)	(7.20)	(-1.57)	(-0.02)	(3.48)	(3.06)	(2.33)
AGE (since IPO)	0.210	-0.257	-0.213***	-1.301	0.252	0.673	0.807
(t-statistic)	(1.01)	(-1.03)	(-2.90)	(-1.35)	(0.79)	(1.34)	(1.43)
Ln (lagged total assets)	1.019***	1.458***	1.464***	24.019***	-6.494***	-14.179***	-16.538***
(t-statistic)	(3.68)	(3.21)	(10.14)	(17.75)	(-7.41)	(-9.02)	(-9.61)
Ln (lagged leverage)	0.010	-0.041***	0.006	0.120***	0.061***	0.106***	0.187***
(t-statistic)	(1.07)	(-3.19)	(1.54)	(3.07)	(2.99)	(3.53)	(5.65)
Ln (lagged market-to-book)	-1.772***	-2.474***	-0.854***	-7.265***	5.367***	7.268***	7.804***
(t-statistic)	(-10.86)	(-9.21)	(-11.23)	(-11.56)	(12.95)	(11.22)	(11.10)
Observations	23,032	23,032	23,032	23,032	23,032	23,032	23,032
Adj. R-squared	0.896	0.851	0.706	0.813	0.626	0.517	0.543
Year FE	YES	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES

Table 7
Comparison of performance changes around acquisitions with control firms matched on four-digit SIC industry and size decile

Panel A: Growth from year t-1 to year t+2

	Cost measures (%)				Profit measures (%)			
	COGS/Sales	SG&A/Sales	D&A/Sales	NOA/Sales	EBITDA/Sales	EBIT/Sales	NI/Sales	EI/Sales
Mean growth								
Acquirer + Target	0.131	-0.747	0.697	-0.716	0.433	0.026	-1.898	-0.856
Control firm	0.216	0.132	0.669	-1.665	-0.743	-1.483	-2.411	-1.564
Mean of A+T - matched Control	-0.084	-0.879	0.028	0.949	1.176	1.509	0.513	0.707
p value	0.660	0.000	0.814	0.314	0.000	0.000	0.361	0.225
Median growth								
Acquirer + Target	0.005	-0.222	0.311	0.323	0.282	0.142	-0.359	0.083
Control firm	0.146	0.159	0.333	-1.394	-0.150	-0.529	-0.859	-0.202
Median of A+T minus Control	-0.002	-0.191	0.006	0.538	0.308	0.272	0.132	0.072
p value	0.492	0.000	0.073	0.000	0.000	0.000	0.027	0.102

Panel B: Growth from year t-1 to year t+5.

	Cost measures (%)				Profit measure (%)s			
	COGS/Sales	SG&A/Sales	D&A/Sales	NOA/Sales	EBITDA/Sales	EBIT/Sales	NI/Sales	EI/Sales
Mean growth								
Acquirer + Target	-0.192	-0.252	0.204	-7.372	0.256	-0.002	-0.453	1.520
Control firm	-0.661	0.043	0.368	-7.579	-0.161	-0.420	-0.584	0.959
Mean of A+T - matched Control	0.470	-0.296	-0.164	0.207	0.417	0.418	0.130	0.562
p value	0.052	0.217	0.154	0.841	0.194	0.260	0.792	0.330
Median growth								
Acquirer + Target	-0.106	-0.235	0.273	-3.385	0.177	0.000	-0.172	0.532
Control firm	-0.510	0.311	0.322	-5.369	-0.072	-0.293	-0.341	0.400
Median of A+T - matched Control	0.068	-0.196	-0.001	0.282	0.246	0.219	0.068	0.061
p value	0.087	0.037	0.562	0.056	0.002	0.007	0.679	0.680

Table 8
Regressions of cost/sales and profit/sales on AGE (from CRSP) for Compustat/CRSP sample

Panel A: Without control variables

	Cost measures (%)				Profit measures (%)		
Dependent Variable	COGS/Sales	SG&A/Sales	D&A/Sales	NOA/Sales	EBIT/Sales	NI/Sales	EI/Sales
Constant	66.776***	20.258***	9.061***	122.005***	3.631***	-0.392*	-7.042***
(t-statistic)	*(202.90)*	*(83.31)*	*(106.71)*	*(104.72)*	*(18.44)*	*(-1.88)*	*(-34.62)*
AGE (from CRSP)	0.021	0.010	0.001	-0.030	-0.035***	-0.001	-0.000
(t-statistic)	*(0.91)*	*(0.59)*	*(0.26)*	*(-0.38)*	*(-2.58)*	*(-0.09)*	*(-0.03)*
Observations	109,662	109,662	109,662	109,662	109,662	109,662	109,662
Adj. R-squared	0.841	0.837	0.748	0.736	0.546	0.458	0.480
Year FE	YES	YES	YES	YES	YES	YES	YES
Firm FE	NO	YES	YES	NO	YES	YES	YES

Panel B: With control variables

	Cost measures (%)				Profit measures (%)		
Dependent Variable	COGS/Sales	SG&A/Sales	D&A/Sales	NOA/Sales	EBIT/Sales	NI/Sales	EI/Sales
Constant	67.658***	22.125***	7.280***	92.222***	3.075***	3.235***	-3.162***
(t-statistic)	*(158.56)*	*(60.30)*	*(49.41)*	*(61.60)*	*(7.59)*	*(6.00)*	*(-5.40)*
AGE (from CRSP)	0.011	0.008	-0.010*	-0.187***	-0.008	0.044***	0.059***
(t-statistic)	*(0.47)*	*(0.45)*	*(-1.85)*	*(-2.69)*	*(-0.61)*	*(2.63)*	*(3.46)*
Ln (lagged total assets)	-0.322**	-0.620***	0.862***	12.822***	-0.178	-2.049***	-2.959***
(t-statistic)	*(-2.37)*	*(-4.40)*	*(13.76)*	*(23.52)*	*(-0.98)*	*(-7.74)*	*(-10.08)*
Ln (lagged leverage)	0.027***	-0.009*	0.013***	0.320***	-0.026***	-0.049***	0.024***
(t-statistic)	*(5.23)*	*(-1.73)*	*(6.70)*	*(17.19)*	*(-4.29)*	*(-6.53)*	*(2.94)*
Ln (lagged market-to-book)	-2.362***	-1.349***	-0.678***	-7.907***	4.481***	4.660***	5.139***
(t-statistic)	*(-25.07)*	*(-12.55)*	*(-16.71)*	*(-23.41)*	*(31.65)*	*(26.20)*	*(26.63)*
Observations	109,662	109,662	109,662	109,662	109,662	109,662	109,662
Adj. R-squared	0.846	0.839	0.759	0.767	0.565	0.477	0.500
Year FE	YES	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES

Table 9

Regressions of profit margin measures (%) on AGE (since incorporation) for private and global firms

Panel A: AMADEUS sample of private European firms

Dependent Variable	EBITDA/Sales	EBIT/Sales	NI/Sales
Constant	11.263***	6.674***	4.322***
(t-statistic)	(20.28)	(12.52)	(7.33)
AGE (since incorporation)	-0.108***	-0.101***	-0.025
(t-statistic)	(-3.21)	(-3.13)	(-0.71)
Observations	1,684,189	1,684,189	1,684,189
Adj. R-squared	0.721	0.579	0.513
Year FE	YES	YES	YES
Firm FE	YES	YES	YES

Panel B: FACTSET global (US and non-US) sample of public firms

Dependent Variable	Gross profits/Sales	EBITDA/Sales	EBIT/Sales	NI/Sales
Constant	29.966***	14.933***	10.284***	3.027***
(t-statistic)	(22.56)	(13.18)	(8.88)	(2.77)
AGE (since incorporation)	-0.215***	-0.176***	-0.191***	-0.056
(t-statistic)	(-3.90)	(-3.73)	(-3.96)	(-1.26)
Observations	366,355	366,355	366,355	366,355
Adj. R-squared	0.751	0.579	0.523	0.418
Year FE	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES

Table 10
Estimates of Cobb-Douglas production functions

Panel A: Compustat/CRSP sample (by industry sector)

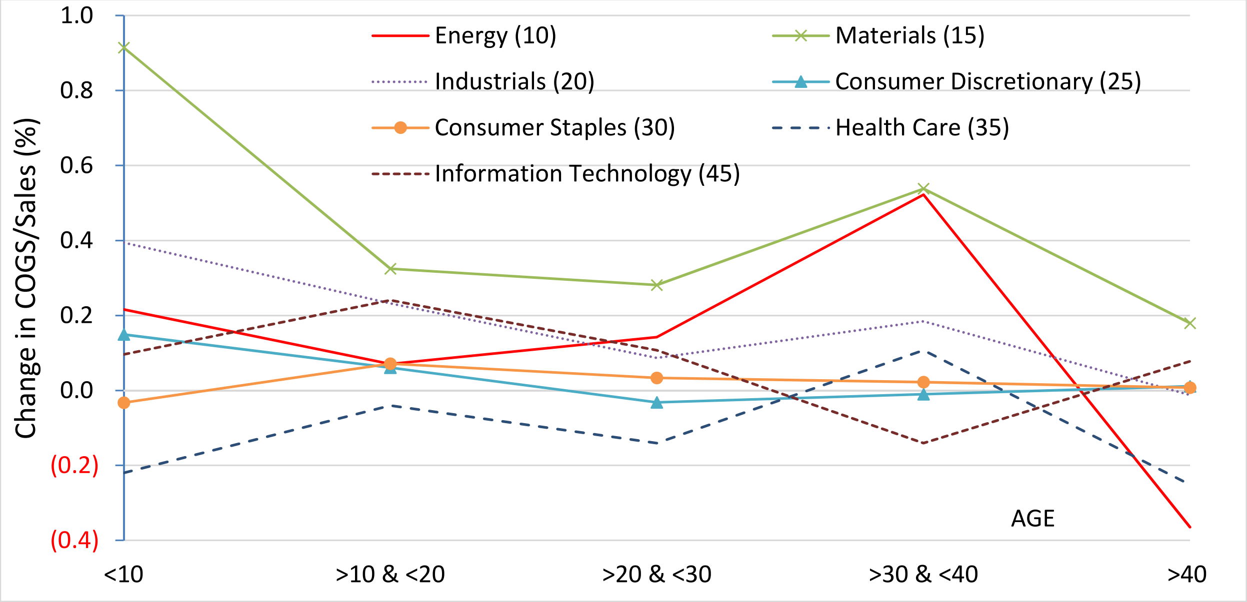
	Sample							
Dep. Var: Ln (Sales)	Full sample	Energy	Materials	Industrials	Cons. Discr.	Cons. Staples	Health Care	Info. Tech.
Ln (net fixed assets)	0.165***	0.240***	0.191***	0.152***	0.228***	0.254***	0.116***	0.158***
(t-statistic)	(19.74)	(4.03)	(7.63)	(7.07)	(8.10)	(6.37)	(5.24)	(12.19)
Ln (# of employees)	0.616***	0.536***	0.578***	0.681***	0.507***	0.422***	0.688***	0.607***
(t-statistic)	(47.08)	(7.56)	(17.15)	(26.50)	(10.49)	(9.00)	(23.10)	(26.78)
Ln (R&D investment)	0.088***	0.014	0.092***	0.072***	0.091***	0.101***	0.076***	0.122***
(t-statistic)	(14.10)	(0.51)	(5.14)	(5.61)	(5.29)	(4.07)	(4.10)	(9.96)
Constant (TFP)	4.870***	3.971***	2.821***	2.915***	2.931***	3.320***	2.431***	2.449***
(t-statistic)	(130.19)	(16.56)	(25.93)	(44.21)	(26.49)	(27.03)	(41.54)	(27.46)
Sum of Cobb Douglas exponents	0.869	0.790	0.861	0.905	0.826	0.777	0.880	0.887
Observations	60,217	1,378	5,025	11,878	6,128	2,718	8,462	20,700
Adj. R-square	0.986	0.992	0.991	0.989	0.985	0.992	0.981	0.978
Year FE	NO	YES	YES	YES	YES	YES	YES	YES
Industry-year FE	YES							
Firm FE	YES	YES	YES	YES	YES	YES	YES	YES

Panel B: Compustat/CRSP sample (by CRSP AGE) and Ritter IPO sample (by AGE since IPO)

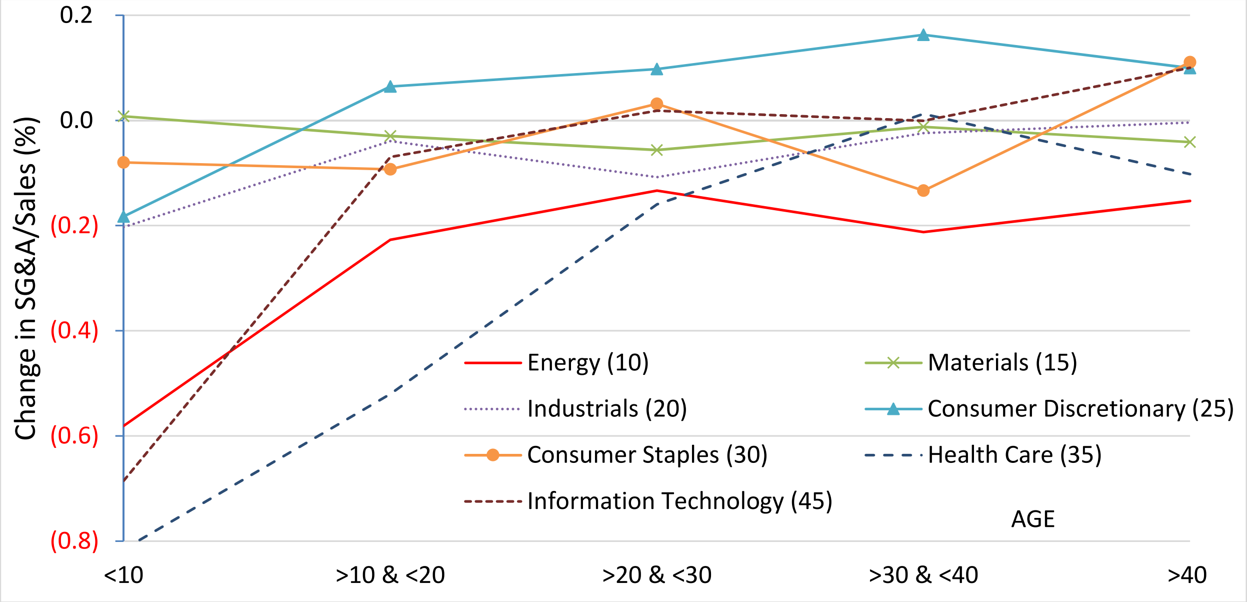
	Compustat/CRSP sample sorted by CRSP AGE					Ritter IPO sample sorted by AGE since IPO				
Dep. Var: Ln (Sales)	AGE≤ 10	10≤ AGE < 20	20≤ AGE < 30	30≤ AGE < 40	40≤ AGE	AGE≤ 5	5≤ AGE < 10	10≤ AGE < 15	15≤ AGE < 20	20≤ AGE
Ln (net fixed assets)	0.138***	0.126***	0.130***	0.165***	0.255***	0.134***	0.136***	0.135***	0.095**	0.120**
(t-statistic)	(11.34)	(9.58)	(5.42)	(4.78)	(9.71)	(4.50)	(5.26)	(5.95)	(2.20)	(2.31)
Ln (# of employees)	0.630***	0.660***	0.621***	0.532***	0.511***	0.563***	0.621***	0.614***	0.616***	0.610***
(t-statistic)	(32.61)	(33.99)	(16.63)	(7.69)	(13.80)	(13.24)	(15.15)	(17.29)	(9.65)	(7.37)
Ln (R&D investment)	0.090***	0.100***	0.096***	0.097***	0.094***	0.102*	0.095**	0.069*	0.152**	0.047
(t-statistic)	(5.21)	(6.57)	(3.04)	(2.94)	(3.29)	(1.96)	(2.47)	(1.69)	(2.55)	(0.43)
Constant (TFP)	4.752***	4.747***	4.828***	4.905***	4.650***	4.663***	4.726***	4.895***	4.659***	5.144***
(t-statistic)	(51.16)	(56.96)	(31.80)	(26.59)	(23.15)	(16.23)	(20.26)	(22.88)	(14.61)	(10.24)
Sum of Cobb Douglas exponents	0.858	0.886	0.847	0.794	0.86	0.799	0.852	0.818	0.863	0.777
Observations	23,320	17,346	7,701	3,755	6,414	6,002	6,680	4,275	2,499	1,825
Adj. R-square	0.982	0.989	0.991	0.994	0.992	0.982	0.983	0.991	0.991	0.990
Year FE	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Industry-year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES

Figure 1: Changes in costs and profits vs. AGE (since incorporation) for Ritter IPO Sample
Under scale efficiencies, changes should be negative (positive) for costs (profits)

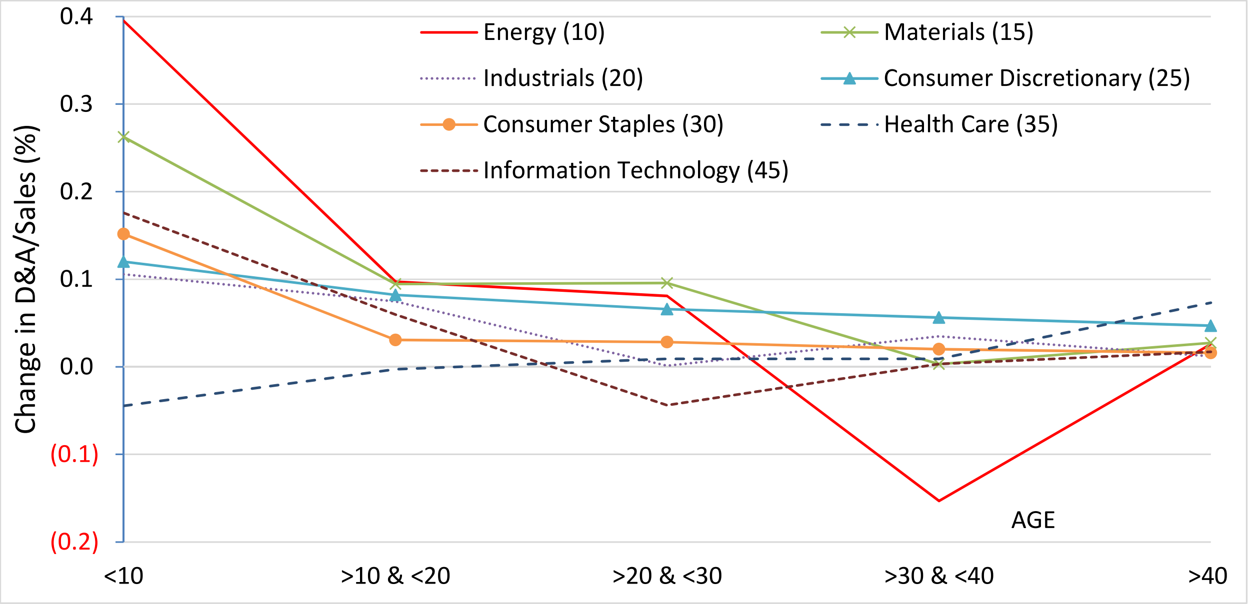
Panel A: Median changes in COGS/Sales.



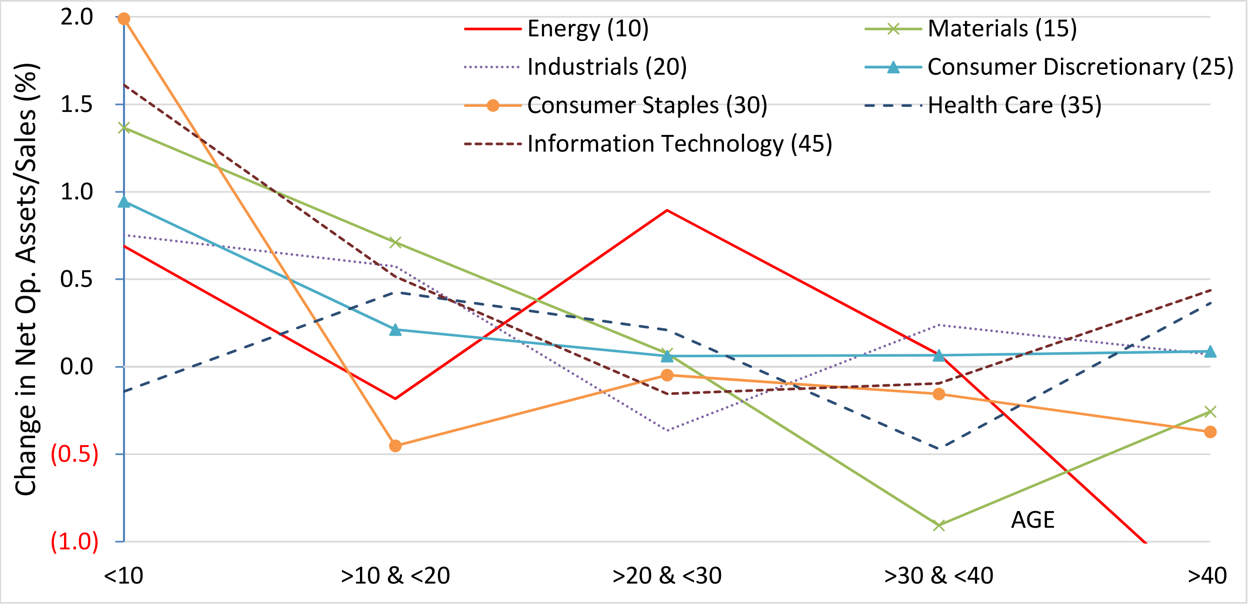
Panel B: Median changes in SG&A/Sales.



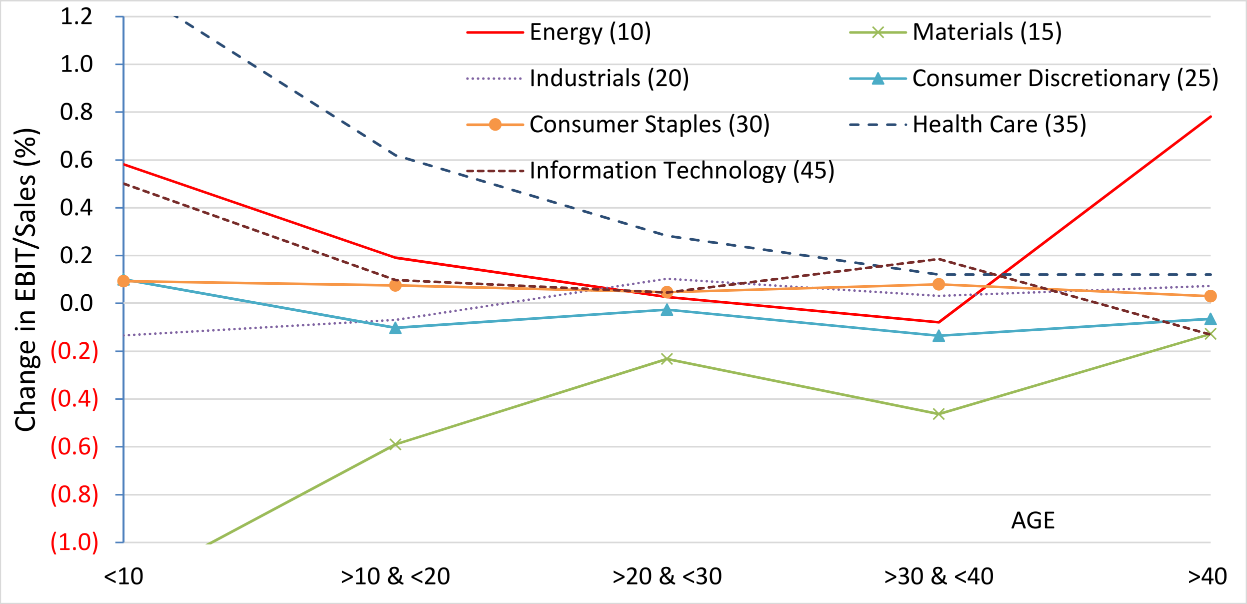
Panel C: Median changes in D&A /Sales.



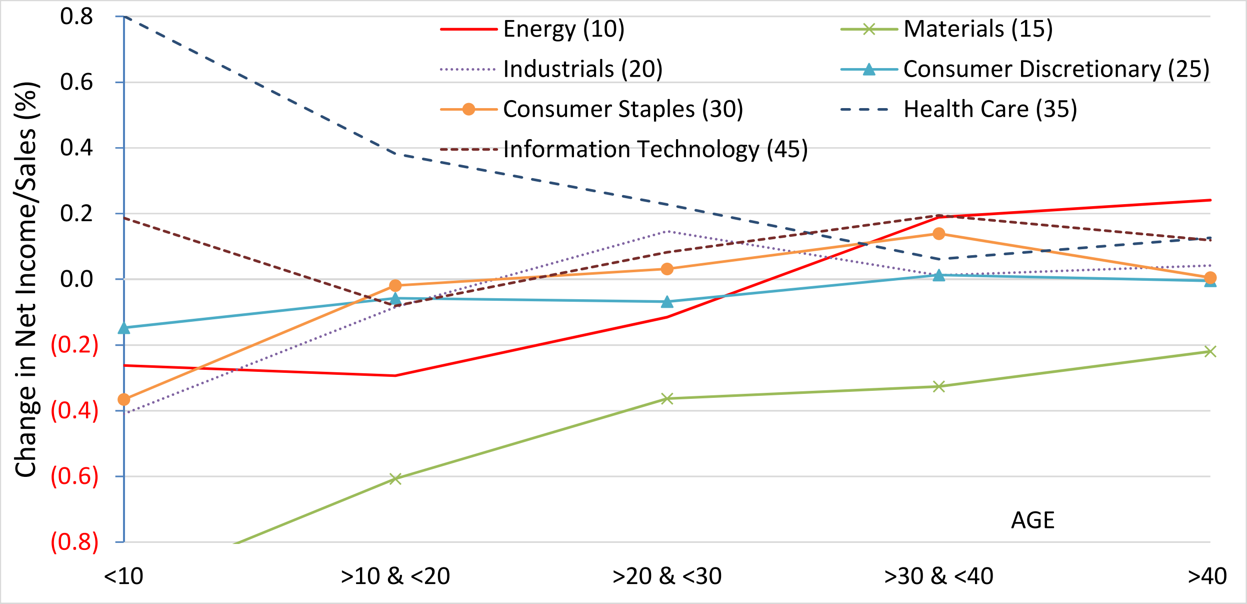
Panel D: Median changes in NOA /Sales.



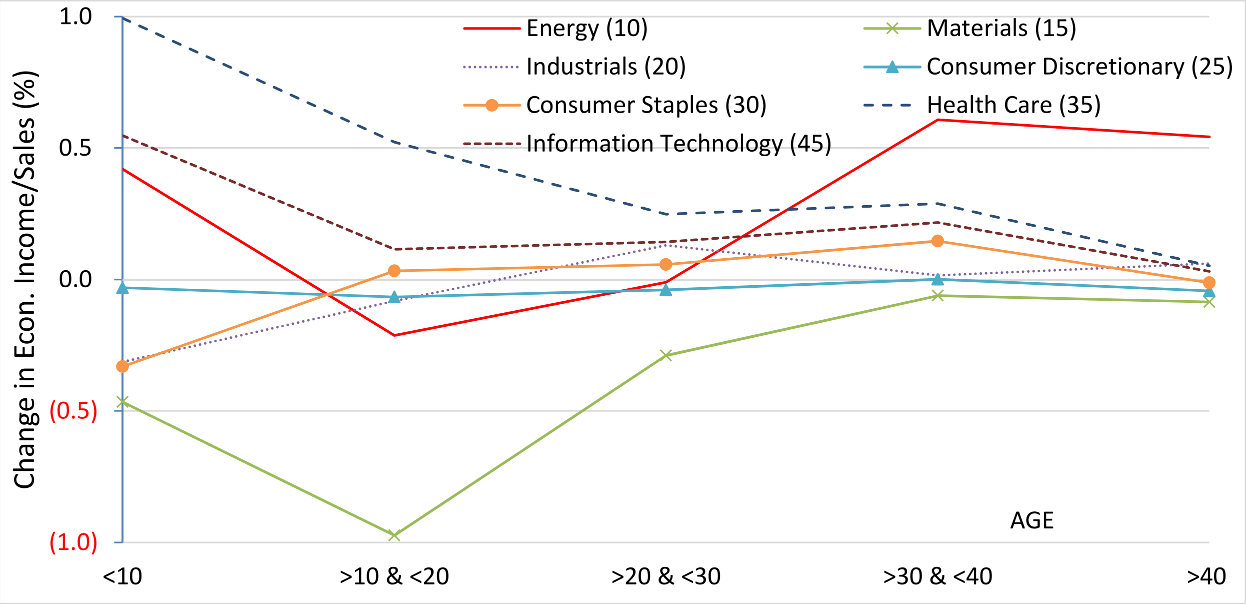
Panel E: Median changes in EBIT/Sales.



Panel F: Median changes in NI/Sales.



Panel G: Median changes in EI/Sales.

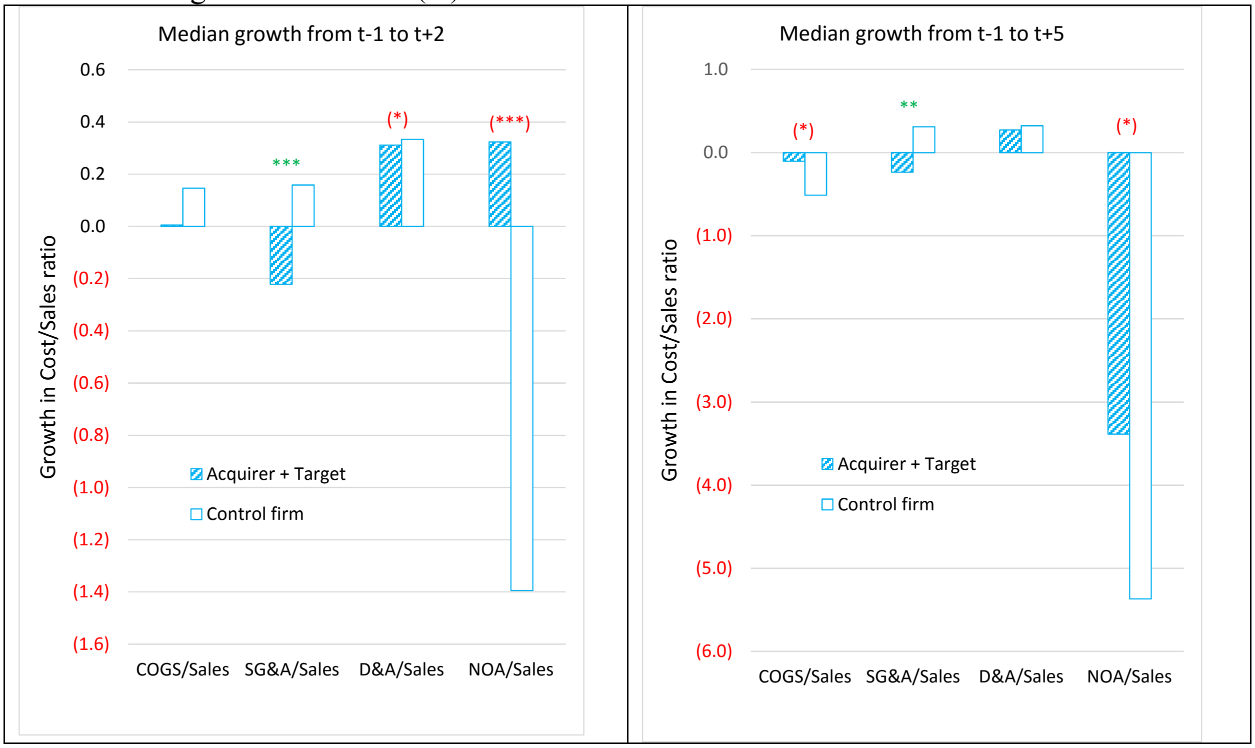


Notes:

Figure 2

Median growth in Costs/Sales and Profits/Sales: from t-1 to t+2 and t+5 (t = acquisition year)

Panel A: Change in Costs/Sales (%)



Panel B: Change in rofits/Sales (%)

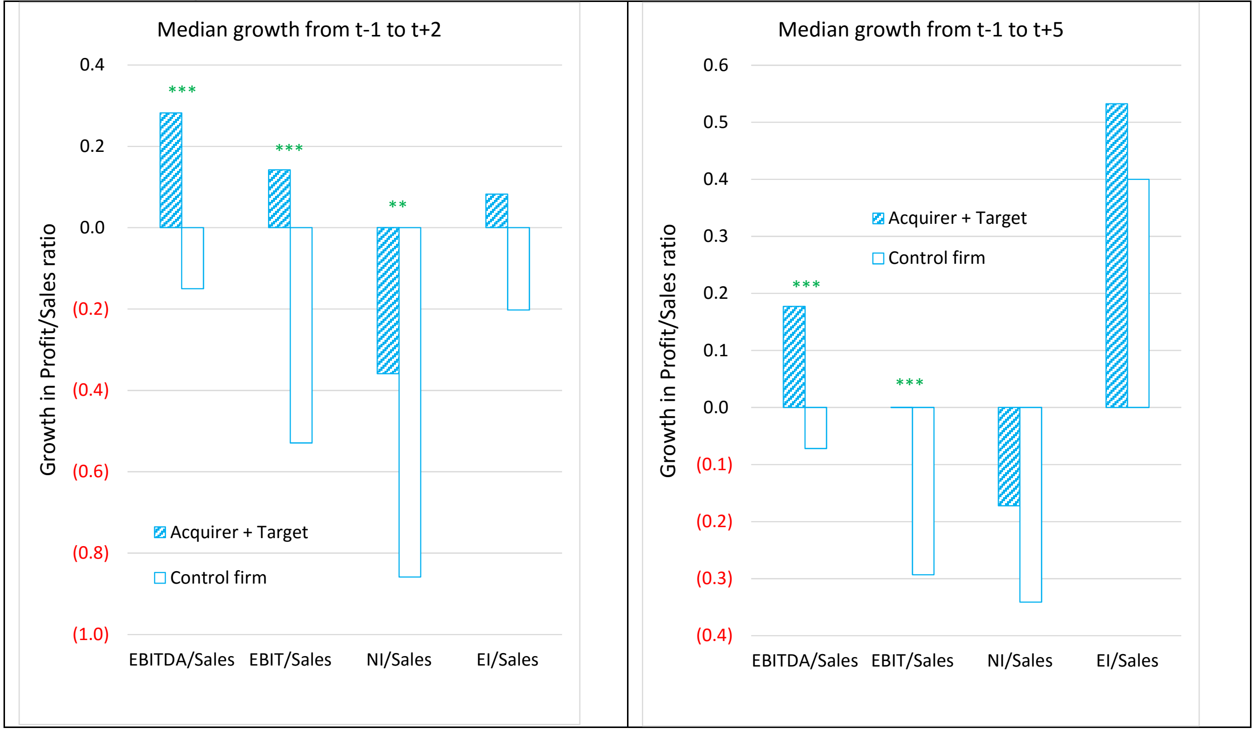
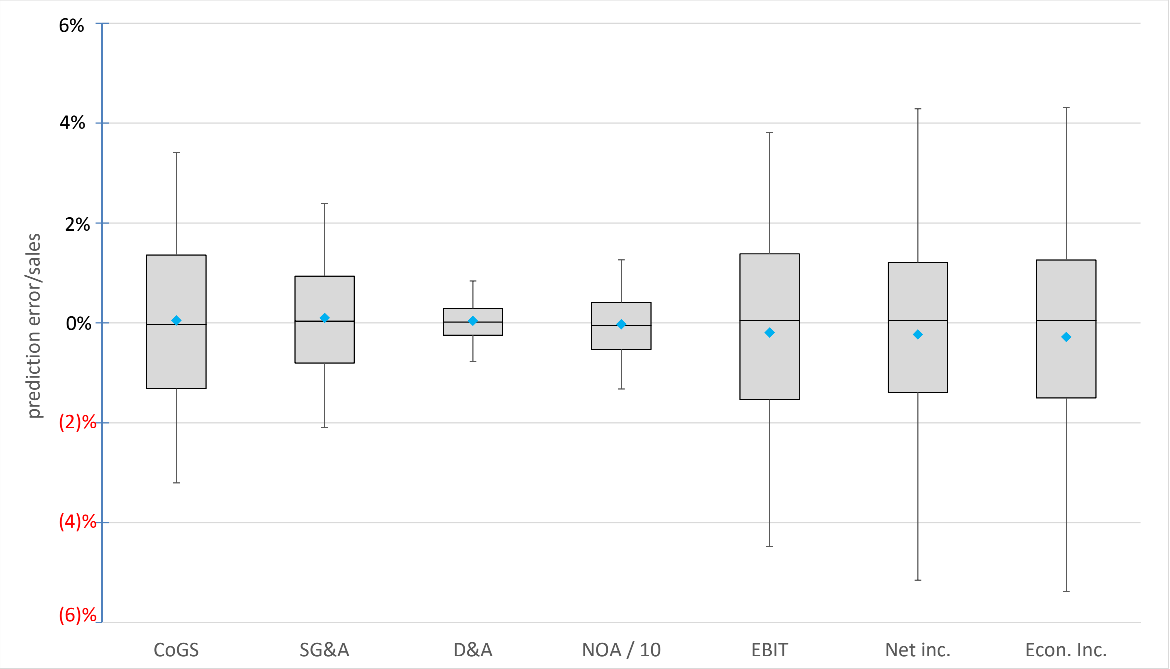


Figure 3
Predicting costs/sales and profits/sales, assuming ratios/margins follow a random walk

Panel A: Costs/Sales and Profits/Sales as % of Sales



Panel B: Costs/Sales as % of predicted values

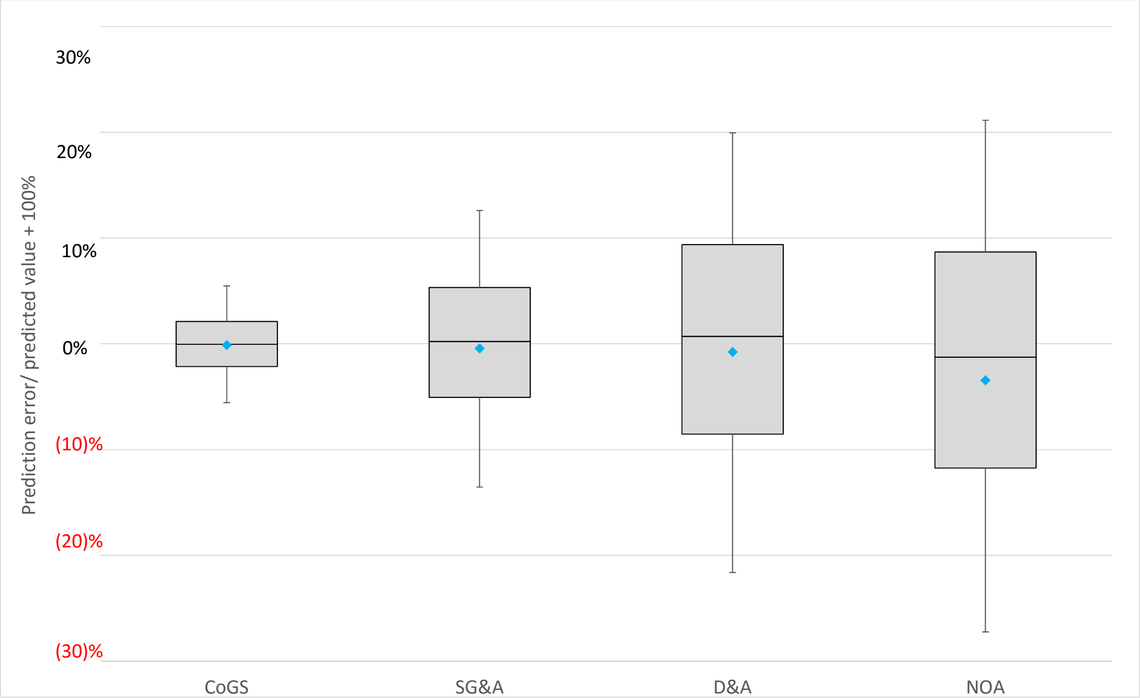


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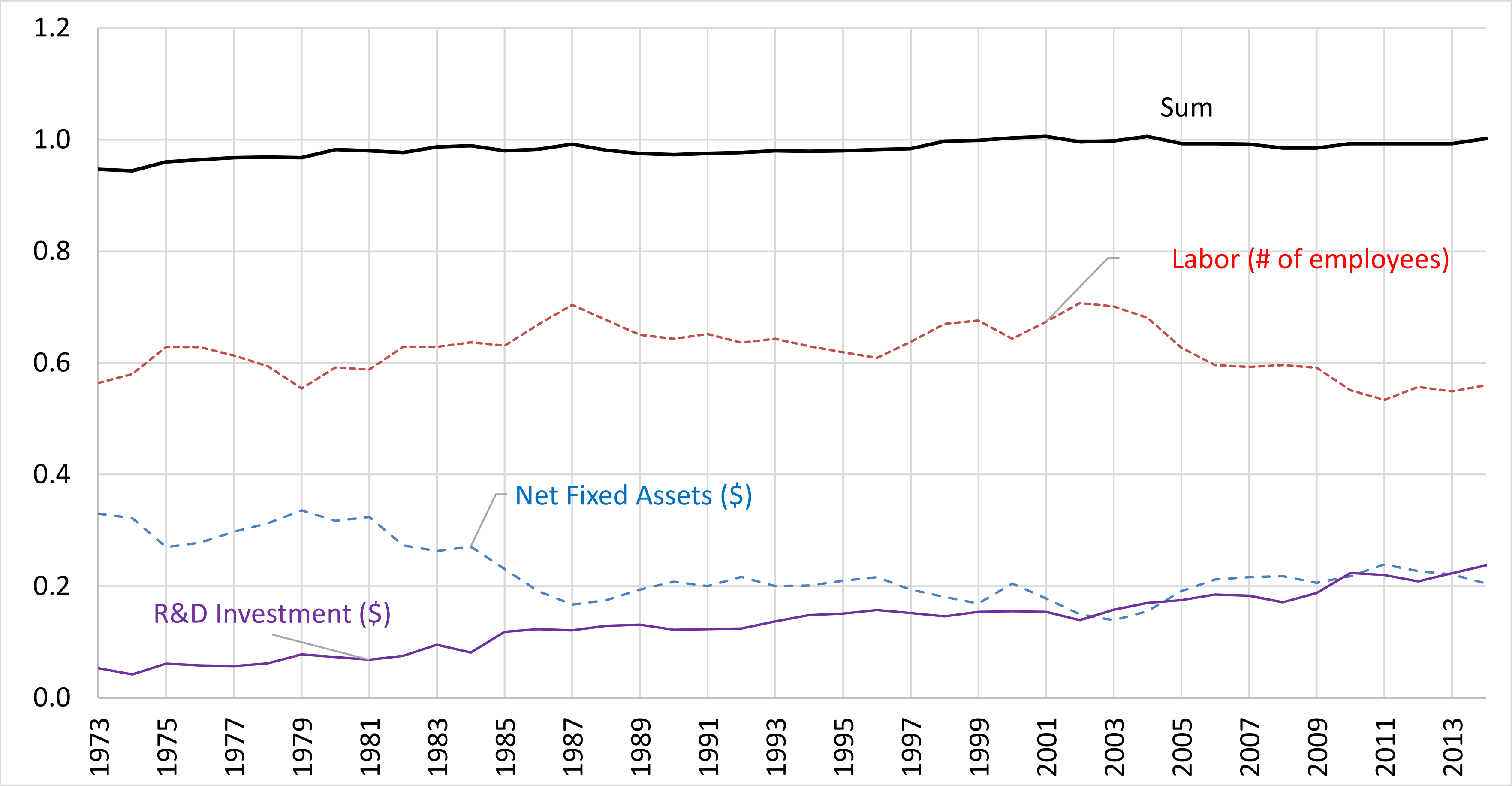
Figure 4
Estimates of Cobb-Douglas exponents for CRSP/Compustat sample.



Note:
Models include industry sector fixed effects
Sums after 1998 are insignificantly different than one