Firm Growth after Dotcom

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Statistical mechanical models have previously been applied to discover and explain the scaling behavior of firm growth for publicly traded manufacturing firms over a wide range of sizes and products. Here we extend the results to internet companies in newly emerging markets. We discover scaling behavior in internet firm growth. In contrast to previous studies, we are able to definitively show the timescale over which such scaling behavior emerges. Our results also exclude certain factors as underlying drivers of power law behavior, and give a clear picture of how the physical concept of universality applies to all corporations.

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I. INTRODUCTION

I.1 Classical Results

In the burgeoning field of Econophysics, much attention has been paid to discovering quantifiable “power laws” that govern economic behavior. In particular, we consider scaling laws describing the growth of firms. The first successful power law description of corporate growth was presented in [1].

The classical economic theory of firm growth, Gibrat’s model, supposes that growth is independent of present size, and uncorrelated in time. These assumptions are equivalent to supposing that the logarithmic growth rates obey a random walk, which yields a log-normal distribution of firm sizes. The Gibrat model is used to benchmark more exact theories, but its failings make it a poor predictor of company dynamics.

An empirical theory of firm growth must account for many factors external and internal, including all types of capital, research and development, and organizational infrastructure. Stanley’s seminal work provides a phenomenological picture of corporate growth based only on initial firm size. It was shown for publicly traded US manufacturing firms in the 1990s that the distribution of growth rates is exponential. Over seven orders of magnitude, the distribution of growth rates decreases with increasing size.

Firm growth rate is defined as $R = S_1/S_0$, where S_1 and S_0 are consecutive annual measures of firm size, and may be equivalently regarded as sales, number of employees, market capitalization, or any number of other commonly used metrics. Likewise, we define $r = \ln(S_1/S_0)$ and $s_0 = \ln(S_0)$. The distribution of growth rates is denoted $p(r|s_0)$.

The distributions for manufacturing firms within the same order of magnitude of initial size were shown to be exponential, rather than Gaussian as would be expected from the Gibrat model. Additionally, the standard deviations of the growth rates of both sales and employees obey a power law dependent on their initial values.

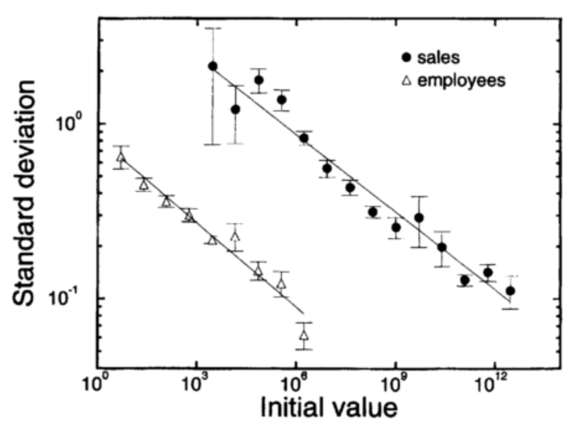

FIG. 1. Standard deviations of growth rate of sales and employees as a function of initial value.

The above scaling laws were demonstrated for a diverse set of manufacturing firms spanning huge ranges in size. Most remarkably, whereas classical economic theory predicts that a firm's growth is dependent on what production technology it requires, which can vary wildly between products, the scaling laws hold for manufacturing firms regardless of what they manufacture.

I.2 Extending beyond manufacturing

In this work we are concerned with extending the above results to firms that have emerged since the foundational literature was published. Since 1996, two entirely new classes of firms have given rise to some of the most dominant economic entities in today's markets. These classes are referred to as "Internet Software & Services," and "E-Commerce." Many companies with annual revenues in the billions of dollars are included in these categories, so-called "internet companies," including Amazon, Google, Facebook, eBay, Netflix, and Twitter.

Unlike the manufacturing firms previously considered – paper, automobile, pharmaceutical, etc. – firms analyzed here do not necessarily sell a physical product or have physical capital. Internet companies do not follow traditional business plans and sometimes do not even have monetization schemes in place. Jeff Bezos, founder of Amazon, spelled out the stark difference between manufacturing firms and internet companies like his own when he said, "We're going to be unprofitable for a long time. And that's our strategy" [2]. Metrics for firm size (e.g. number of employees and market capitalization) were shown to be equivalent for traditional firms, but these metrics may exhibit no correlation for internet companies. This unique feature is exemplified by Amazon, which has experienced incredible growth in revenue while profits remain minimal.

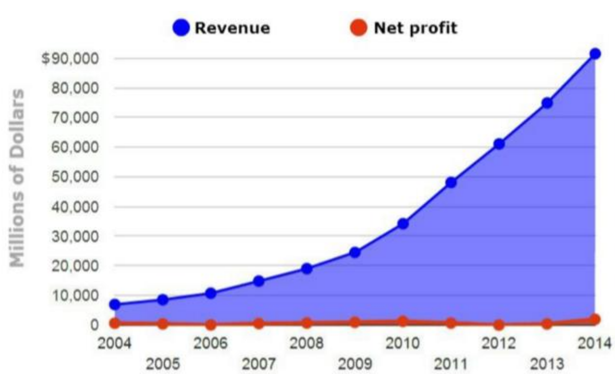

FIG. 2. Revenue and profit for Amazon between 2004 and 2014 [2].

Other typically used measures for firm size also behave atypically for internet companies. A growing manufacturing firm, restaurant, or healthcare provider will necessarily require more employees, while an internet company may offer new products and services provided by the same core teams of programmers, making minimal additions to their employee pool.

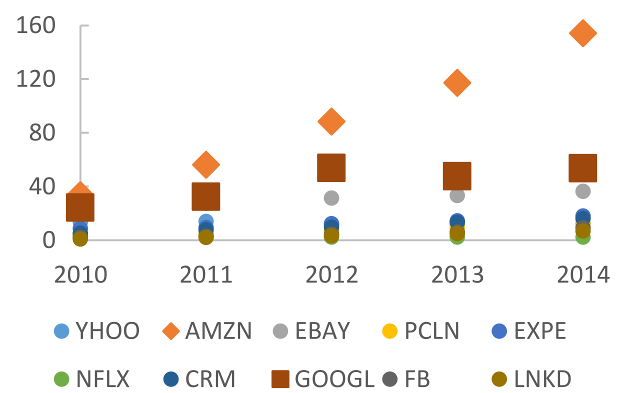

Fig 3. Number of employees (in thousands) from 2010 to 2014 for the ten largest American internet companies by revenue [3].

As illustrated in Figure 3, Amazon exhibits an intuitive trend by maintaining huge growth in number of employees, correlated with their rising revenue. In contrast, other formidable companies like Facebook and even Google add employees at a much slower rate and the trend is not even completely linear, although these companies are still making large gains in revenue over this time period.

Whereas previous studies were concerned with well-established firms in well-established industries (automobile manufacturing, pharmaceuticals, etc.), where some kind of stable equilibrium is assumed to exist, here we are able to analyze the entire history of a new industry. Rather than observing well-behaved power law behavior over many orders of magnitude – indicative of preferential attachment having operated over many years, resulting in equilibrium – we find an evolution from non-correlation to power law, and are able to draw conclusions about the relevant timescales and factors contributing to universal behavior.

II. METHODOLOGY

Data were collected by means of the Compustat database, available through Wharton Research Data Services [3]. Compustat data includes firms representing over 99% of global market capitalization, from 1950 to the present.

Companies were sorted according to the Global Industry Classification Standard (GICS). We were particularly interested in companies falling under the "Internet Software & Services" designation (GICS 45101010).

Number of employees was chosen as the metric to represent firm size. As discussed above, it is unclear if the equivalency of firm size metrics shown for manufacturing firms holds for internet companies. Nevertheless, the results will show that this choice is a reasonable one.

In the final analysis, firms with fewer than 100 employees were neglected. These firms are highly volatile and oftentimes data is not available over a significant timescale. Likewise, firms with greater than 10,000 employees were discarded. There are too few firms in this category (Amazon, Google, etc.) to collect meaningful statistics.

To facilitate comparison between our results and previous analysis of manufacturing firms, we consider the standard deviation of growth rates versus initial firm size, as shown in Figure 1. Lines of best fit and correlation coefficients were computed to quantify agreement with power law behavior.

III. RESULTS

First, we attempt to generalize the results for manufacturing firms to all non-volatile American companies. Firms with greater than 1,000 employees are found to be non-volatile. Strong agreement with power law behavior, correlation coefficient $R^2 > 0.90$, is seen for a wide range of firms with between 1,000 and 100,000 employees.

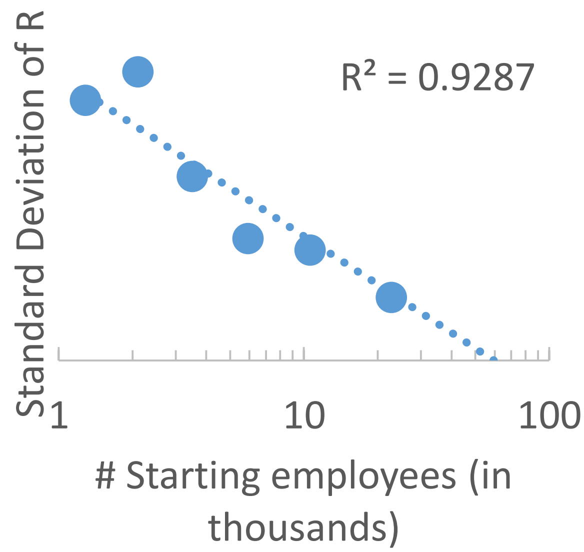

Fig 4. Standard deviation of growth rate, *R*, versus number of employees. All American publicly traded firms with greater than 1,000 employees between the years 2013-2014. A log-scale is used to illustrate power law behavior.

The results indicate a strong tendency towards power law behavior for all publicly traded firms, not only manufacturing. Power law fits can be applied with near 100% goodness of fit when firms are sorted by industry, but the general agreement in Figure 4 suggests that differences between industries do not substantially impact power law behavior. Instead, the 'microscopic' features that differentiate seemingly different industries, e.g. manufacturing versus oil & gas versus insurance, are inconsequential in the face of fundamental scaling laws reminiscent of those found in statistical physics.

With this in mind, we turn to the only large industry where comprehensive data is available from its emergence to the present.

Fig 5. Standard deviation of growth rate, *R*, versus number of employees for "Internet Software & Services" companies over three different fiscal years. A log scale is used to illustrate power law behavior. Number of firms considered and the range of firm sizes is of the same order of magnitude in all three plots.

Figure 5 shows three plots of the same format as those in Figures 1 and 4. Beginning in 2005, one year after Google's initial public offering – which is used as a reference point for the genesis of the internet company era – the plot shows no correlation between firm size and growth rate. Five years later, in 2010, there is some sort of noticeable organization. A power law trend is visible, although the fit agreement is nowhere near that seen for all firms or manufacturing firms. Finally, in 2013 (the most recent year for which comprehensive data for all internet companies is available), scaling behavior is clear. As expected, larger companies exhibit much smaller deviation in growth rates, while smaller companies are more prone to experiencing great surges in growth, or crashing.

There was not a substantial increase in the number of firms considered from 2005 to 2013, and the range of firm sizes is also static. Therefore, we conclude that for firms, the emergence of scaling behavior is not dependent on an industry reaching some critical size or spanning a critical range of firm sizes. Instead, scaling behavior emerges for the firms in any industry, regardless of the 'microscopic' details that determine its unique features, and internal variables that specify the industry's state. However, scaling behavior is dependent on timescale, and here we have shown one example of the macro-scales (on the order of a decade), involved in the self-organization of firms within an industry.

The plots in Figure 5 illustrate the evolution from random disorder at the birth of an industry to the self-organization evident after almost ten years. Internet companies, despite not adhering to many of the constraints that apply to other firms, exhibit the same sort of scaling behavior.

IV. CONCLUSION

The results presented above enhance our understanding of the fundamental laws at work in firm organization and expansion. By extending well-known work on the scaling behavior of manufacturing firm growth, we have probed the statistical mechanical universality underlying all corporate growth.

Internet companies were found to display the same scaling behavior in their growth rates as manufacturing firms. Despite their lack of property, plant & equipment, physical product, and sometimes even physical office and/or retail space, internet companies obey universal scaling laws in their growth.

We have shown that universal scaling applied to growth rates does not depend on production technology, as conventional economic theory of the firm suggests, nor does it depend on the intuitively obvious correlations between profit, revenue, number of employees, market capitalization, or various measures of capital that characterize non-internet companies. Indeed, internet companies like Amazon, Facebook, and Twitter are sometimes completely lacking in monetization schemes and follow completely novel, 21st century business plans that would lead to catastrophic failure for firms in any other industry. For these reasons, typical measures of firm size may be completely uncorrelated in internet companies. A "successful" internet company is often defined as one with rapidly growing revenue and an ever-expanding portfolio of services and market monopolization, rather than growing profits.

Nevertheless, we have shown how internet companies have, only in the last few years, evolved from total disorganization to obey previously discovered scaling laws. Analysis indicated that the emergence of scaling behavior in publicly traded internet companies occurred on a timescale of about a decade.

The work presented here strengthens the argument for validity of scaling phenomena applied to the growth of firms, and for the statistical mechanics model of firm growth. We have generalized classic results to encompass not only manufacturing firms, but also firms in new, emerging markets. This work might offer insight into the future evolution of emerging industries in the coming age of the "Internet of Things."

1. ACKNOWLEDGEMENTS

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