Maximum-Entropy Models of Profit-Rate Distributions: Evidence from Chinese Industrial Firms

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Abstract

Classical political economy describes competition as a process that moves capital toward sectors with higher profits and thereby tends to equalize profit rates. A statistical-equilibrium approach draws the implication that competition produces not a single uniform rate of profit but a stable distribution of profit rates across firms. This paper studies the firm-level distribution of profit rates in China using the Chinese Industrial Enterprises Database for 1996–2007. The distribution is sharply peaked and asymmetric, and a substantial share of firms, ranging from about one-half in 1996–1997 to about one-tenth in 2007, report negative profit rates. We compare four maximum-entropy models of the profit-rate distribution: the exponential, Gamma, asymmetric Laplace, and quantal response statistical equilibrium (QRSE) distributions. The asymmetric Laplace distribution, which accommodates both negative and positive profit rates, fits the data closely in every year, and the QRSE model captures its overall shape. The estimated parameters show that the mean profit rate rises over the period, while the lower tail of the distribution contracts and the upper tail lengthens. We discuss what these changes may reveal about competition and firm exit, and outline how a formal model comparison can be carried out in future work.

Keywords: rate of profit, statistical equilibrium, maximum entropy, quantal response, asymmetric Laplace distribution, China
JEL codes: B51, C11, D21, L11, P23

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1 Introduction

A conventional, deterministic notion of equilibrium holds that market outcomes, whether prices, rates of profit, or quantities, converge to a single value. Equilibrium is then understood as a state of uniformity (Scharfenaker and Semieniuk, 2017). Everyday experience suggests otherwise. On April 22, 2024, a pound of organic Honeycrisp apples of roughly the same quality sold for $2.99 at Costco, $2.34 at Smith's, and $2.49 at Target in Salt Lake City. Under a deterministic notion of equilibrium, all trades of the same good on the same day in the same city should take place at the same price. A probabilistic approach instead holds that a range of prices, or of profit rates, is consistent with equilibrium, and that the object to be explained is the *distribution* of outcomes rather than a single number. This view is better suited to phenomena that arise from the decentralized interaction of many agents.

The rate of profit is a natural object for this approach. Since the eighteenth century, classical economists have treated it as the central regulator of capitalist economies. Adam Smith and Karl Marx both describe competition as a process in which capital moves toward sectors with higher profit rates and away from sectors with lower ones, a process that tends to equalize profit rates across the economy without ever establishing a single uniform rate (Smith, 2007; Marx, 1998). The classical economists also observed a secular decline in the general rate of profit during the late eighteenth and early nineteenth centuries and offered competing explanations for it: Smith attributed it to the growing abundance of capital (Verdera, 1992; Tsoulfidis and Paitaridis, 2012), Ricardo (1891) to diminishing returns in agriculture, and Marx to the rising organic composition of capital, which he regarded as a central source of economic crises (Sweezy, 1942; Foley, 1986; Heinrich, 2012; Basu, 2018). Whatever its long-run trend, the rate of profit shapes investment and accumulation, so how it is distributed across firms, and how that distribution changes, is itself informative about the state of competition.

Most empirical studies of the rate of profit rely on aggregate time series and on frequentist methods. A growing literature instead models the firm-level distribution of profit rates as a statistical equilibrium, derived from the principle of maximum entropy subject to constraints that encode economic theory (Farjoun and Machover, 1983; Alfarano et al., 2012; Scharfenaker and Semieniuk, 2017, 2025). Different constraints yield different distributions, so comparing how well these distributions fit the data amounts to comparing the theories of competition that underlie them. Before such theories can be brought to bear on the rate of profit, it is necessary to establish which distribution the data support.

Nearly all of this literature uses firm-level data for the United States. This paper examines whether the distributions proposed in that literature describe the profit rates of Chinese industrial enterprises. China provides an informative case. Although it is a socialist market economy, the rate of profit is a central variable in its economy, and the period we study, 1996–2007, saw rapid enterprise restructuring and growth. Using the Chinese Industrial Enterprises Database, we fit four maximum-entropy distributions to the annual distribution of firm profit rates: the exponential, Gamma, asymmetric Laplace, and quantal response statistical equilibrium (QRSE) distributions.

We find that the distribution of profit rates in China is sharply peaked and asymmetric, with a substantial mass of firms reporting losses. The asymmetric Laplace distribution, which accommodates both negative and positive profit rates, fits the data closely in every year, and the QRSE model captures the overall shape of the distribution. Over the period, the mean profit rate rises, the lower tail of the distribution contracts, and the upper tail lengthens.

The rest of the paper is organized as follows. Section 2 discusses the frequentist and Bayesian approaches to inference and reviews the literature on profit-rate distributions. Section 3 presents the four models and their economic interpretation. Section 4 describes the data, Section 5 presents the estimates and the comparison of the models, and Section 6 concludes.

2 Background

2.1 Frequentist and Bayesian inference

Frequentist and Bayesian approaches differ in how they frame probability statements, and these differences reflect different views of how to interpret and model observed phenomena. The distinctions and their implications have been examined extensively in the statistical literature (Pratt, 1965; Rubin, 1984; Bayarri and Berger, 2004). Frequentist methods rest on the contributions of Fisher, Pearson, and Neyman, whose principles underlie null hypothesis significance testing and the construction of confidence intervals. Bayesian methods rest on Bayes' rule for conditional probability. They express prior information about the quantities of interest as probability distributions and update it in light of the data to obtain posterior distributions. Both approaches aim at sound statistical inference, and many frequentist procedures can be interpreted as Bayesian procedures under particular prior assumptions (Bayarri and Berger, 2004). We adopt the Bayesian perspective, which treats the parameters and hypotheses of interest as uncertain and the observed data as given, and which combines naturally with the principle of maximum entropy (Foley and Scharfenaker, 2026). The estimates reported below minimize the Kullback–Leibler divergence between the empirical and model distributions, which is equivalent to maximizing the likelihood of the binned data and hence to finding the posterior mode under uniform priors.

2.2 The distribution of profit rates

Farjoun and Machover (1983) were the first to propose that the rate of profit follows a Gamma distribution, by analogy with statistical mechanics, although they did not develop the economic meaning of the constraints that generate it in much detail. Alfarano et al. (2012) find that the empirical density of firm profit rates is well described by an exponential power, or Subbotin, distribution. Scharfenaker and Semieniuk (2017) show that profit rates of publicly listed North American firms are well described by a Laplace distribution, and Scharfenaker and Semieniuk (2025) derive a Gamma distribution for capital-weighted profit rates and give an economic interpretation of its constraints.

The idea that profit rates are distributed over a range rather than equal to a single value has deep roots in classical political economy. Smith (2007) argues that the pursuit of higher profits creates a tendency toward the equalization of profit rates across competitive sectors, and Marx (1998) describes how capital flows into sectors with higher profit rates. Both accounts imply a tendency toward equalization, not a state of uniformity, and hence a distribution of profit rates across firms and sectors.

Since most research on the distribution of profit rates uses microdata for the United States, evidence for China is scarce. Our study fills this gap by examining whether the distributions proposed in the literature describe the profit rates of Chinese industrial enterprises.

3 Statistical Equilibrium Models of the Profit Rate

Each model we consider is the distribution $p(x)$ of the profit rate x that maximizes Shannon entropy subject to a set of constraints. The constraints represent the information that economic theory provides about the process generating profit rates, and the maximum-entropy distribution is the least biased distribution consistent with that information.

3.1 Exponential and Gamma distributions

We begin with the exponential distribution, since one of its constraints is shared by the Gamma distribution. This allows us to assess whether the additional constraint of the Gamma distribution changes the fit substantially. The *exponential distribution* solves

$$\max_{p(x)\geq 0} -\int_0^\infty p(x)\log p(x)\,dx \quad \text{s.t.} \quad \int_0^\infty p(x)\,dx = 1, \qquad \int_0^\infty x\,p(x)\,dx = \bar{r}. \tag{1}$$

The constraint on the mean profit rate has a natural economic interpretation. In the Marxian account, total profits equal total surplus value, which is bounded because the working day and the labor force are limited. Profits, and hence profit rates, are therefore bounded on average (Scharfenaker and Semieniuk, 2017).

The *Gamma distribution*, $p(x) \propto e^{-\alpha \log x - \beta x}$, solves

$$\max_{p(x)\geq 0} -\int_0^\infty p(x)\log p(x)\,dx \quad \text{s.t.} \quad \int_0^\infty p(x)\,dx = 1, \qquad \int_0^\infty x\,p(x)\,dx = \bar{r}, \qquad \int_0^\infty p(x)\log\frac{x}{\bar{r}}\,dx = \tilde{r}. \tag{2}$$

The additional constraint limits the difference between the expected rate of profit of a firm and the average rate of profit. A firm whose profit rate falls too far below the average has an incentive to exit and move its capital to sectors with higher profit rates, which limits the dispersion of profit rates around the average (Scharfenaker and Semieniuk, 2017).

3.2 The asymmetric Laplace distribution

Negative profit rates are a feature of real economies. Firms may survive losses for some time, for example with the support of government programs for struggling industries. In our data, at least 10 percent of firms report negative profit rates in every year (Table 1), so disregarding them would be unjustified. The exponential and Gamma distributions are defined only for positive values, so we also consider two models that accommodate both positive and negative profit rates.

Table 1: Share of firms with negative profit rates

Year	Share	Year	Share
1996	0.501	2002	0.240
1997	0.511	2003	0.182
1998	0.345	2004	0.197
1999	0.319	2005	0.159
2000	0.271	2006	0.136
2001	0.276	2007	0.109

The *asymmetric Laplace distribution* solves

$$\begin{aligned} \max_{p(x)\geq 0} \; -\int_{-\infty}^{\infty} p(x)\log p(x)\,dx \quad \text{s.t.} \quad & \int_{-\infty}^{\infty} p(x)\,dx = 1, \\ & \int_{-\infty}^{\mu} (\mu - x)\,p(x)\,dx = c_1, \qquad \int_{\mu}^{\infty} (x-\mu)\,p(x)\,dx = c_2, \end{aligned} \tag{3}$$

where μ is the mode of the distribution. The solution is the asymmetric Laplace density

$$p(x; c_1, c_2, \mu) = \frac{1}{\left(\sqrt{c_1}+\sqrt{c_2}\right)^2} \begin{cases} \exp\left(\dfrac{x-\mu}{\sqrt{c_1 c_2}+c_1}\right) & \text{if } x \leq \mu, \\ \exp\left(-\dfrac{x-\mu}{\sqrt{c_1 c_2}+c_2}\right) & \text{if } x > \mu. \end{cases} \tag{4}$$

The two constraints can be interpreted in terms of two groups of firms: c_1 constrains the mean deviation of firms with profit rates below the mode, and c_2 the mean deviation of firms with profit rates above it. Firms with profit rates below the mode typically face stronger pressure to exit than firms above it, so we may expect c_1 to be smaller than c_2. Scharfenaker and Semieniuk (2017) show that these constraints are consistent with a classical theory of competition, in which profitability is assessed relative to a general rate of profit that regulates the allocation of capital. There is no reason to assume a priori that the pressures acting on capital earning less than the general rate are the same as those acting on capital earning more.

3.3 The quantal response statistical equilibrium model

The *QRSE model* (Scharfenaker and Foley, 2017; Foley and Scharfenaker, 2026) describes the joint distribution of the profit rate x and the action a of capitalists, who may enter or exit a sector. It maximizes the joint entropy of profit rates and actions,

$$
\begin{aligned}
&\max_{p(x),\, p(a|x)} \quad H[p(x)] + \int p(x)\, H[p(a \mid x)]\, dx \\
&\text{s.t.} \quad \int p(x)\, dx = 1, \qquad \int p(x) \tanh\!\left(\frac{x-\mu}{T}\right)(x-\alpha)\, dx = \delta,
\end{aligned}
\tag{5}
$$

where $H[\cdot]$ denotes Shannon entropy and $p(a \mid x)$ is a logit quantal response describing the probability of entry or exit at a given profit rate,

$$
p(\text{entry} \mid x) = \frac{1}{1+e^{-(x-\mu)/T}}, \qquad p(\text{exit} \mid x) = \frac{1}{1+e^{(x-\mu)/T}}. \tag{6}
$$

The resulting marginal distribution of profit rates depends on four parameters: the *tipping point* μ, the profit rate at which capitalists are equally likely to enter and to exit; the *behavioral temperature* T, which measures the dispersion of their responses around the tipping point; the *central tendency* α of the distribution; and a scale parameter S, which reflects the strength of the feedback of entry and exit on profit rates. The additional constraint captures Smith's account of competition: the entry of firms into a sector lowers its profit rate, and their exit raises it (Foley and Scharfenaker, 2026). The model thus combines the behavior of individual capitalists with the feedback of their actions on the distribution of profit rates.

4 Data

The data come from the Chinese Industrial Enterprises Database for 1996–2007. The database is compiled annually by the National Bureau of Statistics and covers industrial legal entities with annual main business income of 5 million yuan or more. By 2007 it covered more than 330,000 industrial enterprises, accounting for about 95 percent of China's total industrial output (Nie et al., 2012). Although enterprises enter and exit the database each year, most are observed continuously. The database contains considerably fewer enterprises in 1996 and 1997 than in later years, so the results for these two years should be interpreted with caution.

We measure the profit rate as the ratio of operating profit to total assets. We drop observations with missing, zero, or negative total assets, observations with eight or fewer employees, and observations with missing operating profit. To limit the influence of outliers, we then retain, in each year, only observations whose profit rate lies between the 5th and 95th percentiles. Table 2 reports the number of observations at each stage, and Table 3 the summary statistics of the profit rate after cleaning.

Figures 1 and 2 show the annual distributions of the profit rate. The distributions are sharply peaked near zero and asymmetric, with a longer right tail. Their shape resembles an asymmetric Laplace distribution. To assess this systematically, we fit each of the four models to the data for every year.

Table 2: Number of observations

Year	Original	After cleaning	After trimming
1996	23,699	23,370	21,032
1997	24,126	23,490	21,140
1998	165,118	158,476	142,628
1999	162,033	154,979	139,481
2000	162,885	156,365	140,727
2001	171,256	166,429	149,785
2002	181,491	177,123	159,409
2003	194,079	190,918	171,826
2004	279,092	271,816	244,634
2005	271,674	268,784	241,904
2006	301,502	297,700	267,930
2007	336,123	333,059	299,753

Note: Trimming retains observations between the 5th and 95th percentiles of the profit rate in each year.

Table 3: Summary statistics of the profit rate

Year	Min.	1st quartile	Median	Mean	3rd quartile	Max.
1996	−0.150	−0.033	−0.000	−0.010	0.015	0.100
1997	−0.144	−0.035	−0.000	−0.011	0.012	0.098
1998	−0.140	−0.014	0.006	0.022	0.048	0.304
1999	−0.118	−0.009	0.008	0.024	0.049	0.278
2000	−0.101	−0.002	0.011	0.031	0.055	0.281
2001	−0.100	−0.003	0.014	0.035	0.062	0.293
2002	−0.090	0.000	0.019	0.041	0.070	0.304
2003	−0.075	0.000	0.025	0.049	0.080	0.320
2004	−0.086	0.001	0.026	0.051	0.082	0.345
2005	−0.074	0.006	0.037	0.069	0.104	0.458
2006	−0.066	0.008	0.041	0.078	0.113	0.508
2007	−0.054	0.012	0.050	0.097	0.136	0.628

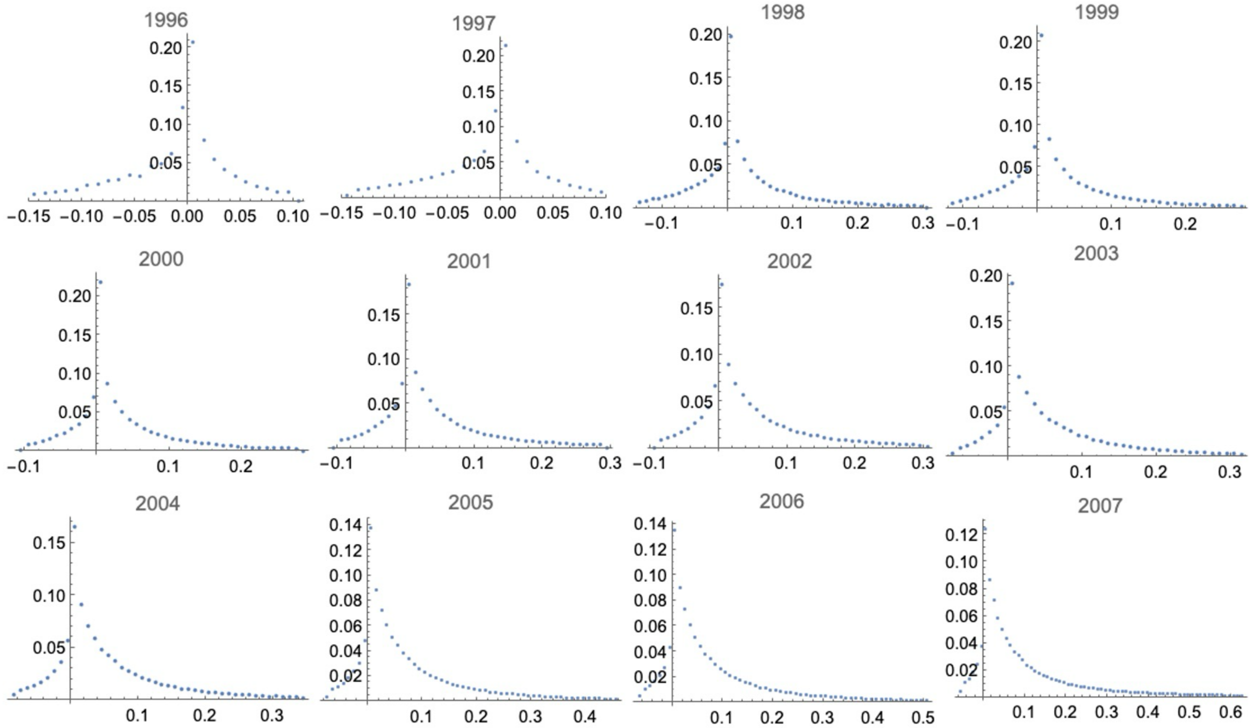

Figure 1: Distribution of firm profit rates, unweighted, 1996–2007.

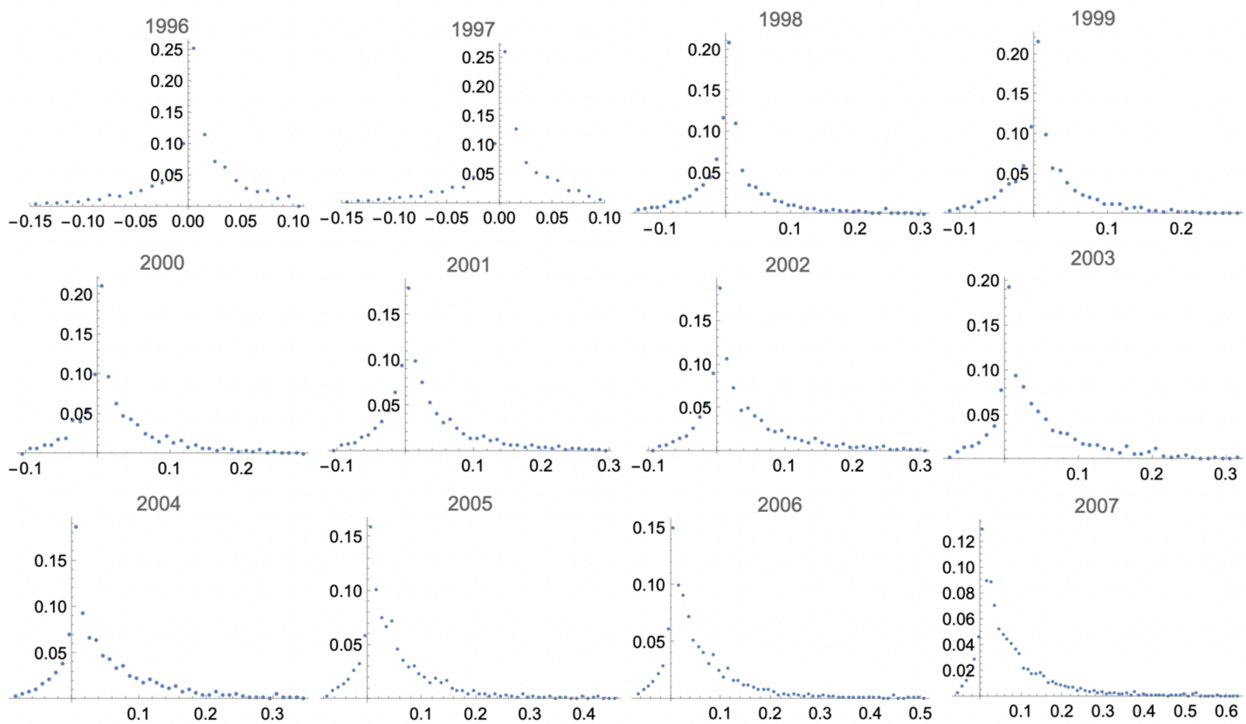

Figure 2: Distribution of firm profit rates weighted by capital, 1996–2007. Each firm is weighted by its share of total assets in that year.

5 Results

For each year, we bin the profit rates into intervals of width 0.01 and estimate the parameters of each model by minimizing the Kullback–Leibler divergence between the empirical bin frequencies and the model distribution, using numerical minimization in *Mathematica*. Minimizing this divergence is equivalent to maximizing the likelihood of the binned data. The models are fitted to different versions of the data, reflecting their supports. The exponential and Gamma distributions, which are defined only for positive values, are fitted to the capital-weighted distribution of positive profit rates. The asymmetric Laplace distribution is fitted to the full capital-weighted distribution, and the QRSE model to the full unweighted distribution.

5.1 Exponential and Gamma distributions

Figure 3 shows the estimated exponential and Gamma distributions together with the capital-weighted empirical distribution of positive profit rates, since both distributions are defined only for positive values. The two estimated distributions are very similar in shape and location, and both follow the general decline of the density. Their fit is closer in later years than in 1996–1999, when the estimated curves lie above much of the empirical distribution.

Figure 4 shows the evolution of the estimated parameters. The mean of both distributions rises steadily over the period, from about 0.03 in 1996–1997 to about 0.09 in 2007. This rising mean profit rate runs counter to Marx's hypothesis of a falling rate of profit. Twelve years of data are not sufficient to refute a hypothesis about long-run tendencies, however, and the rising mean may reflect the particular circumstances of Chinese industry in this period. Longer series are needed to draw conclusions about the long-run relationship between profit-rate dynamics and Marx's hypothesis.

5.2 Asymmetric Laplace distribution

Figure 5 shows the estimated asymmetric Laplace distribution together with the capital-weighted empirical distribution. It fits the data closely in every year. This supports the view that the rate of profit is distributed as an asymmetric Laplace random variable, in line with the findings of Scharfenaker and Semieniuk (2017) for North American firms. The shape of the distribution changes over time, however. In the early years it has a pronounced left tail, and in later years a pronounced right tail, which indicates that its parameters evolve.

Figure 6 shows the evolution of the parameters. The mode μ is essentially constant at about 0.005, while c_1 falls steadily and c_2 rises. In a market close to perfect competition, persistently high profit rates would attract entry and be competed away, so c_2 should remain constant or decline. The rise in c_2 instead suggests that firms with persistently high profit rates emerged over the period, which may indicate growing market power. Conversely, low profit rates can persist when firms receive government support that allows them to remain in the market despite low profitability. The decline in c_1 suggests that firms with low profit rates increasingly exited the market, consistent with a weakening of such support over the period.

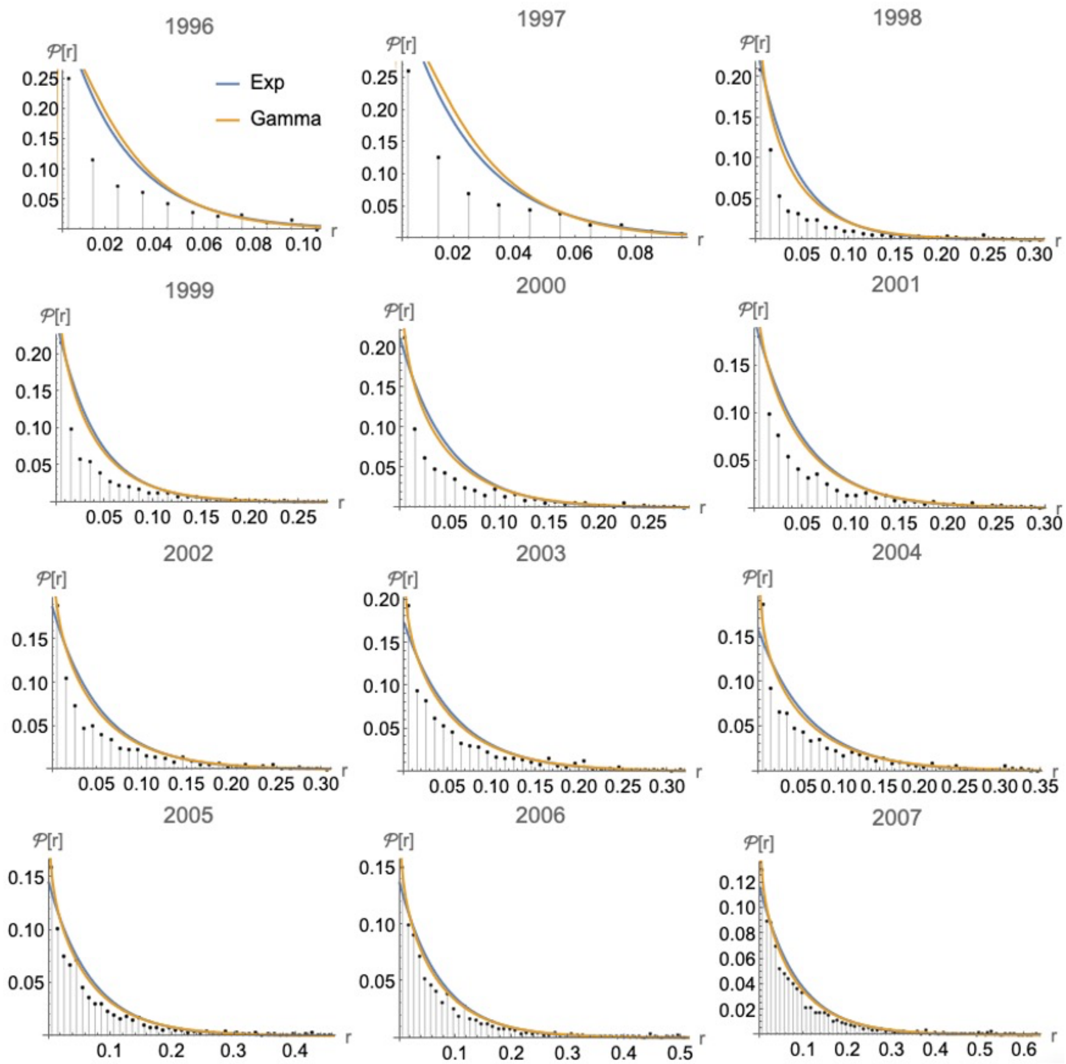

Figure 3: Estimated exponential and Gamma distributions, 1996–2007.

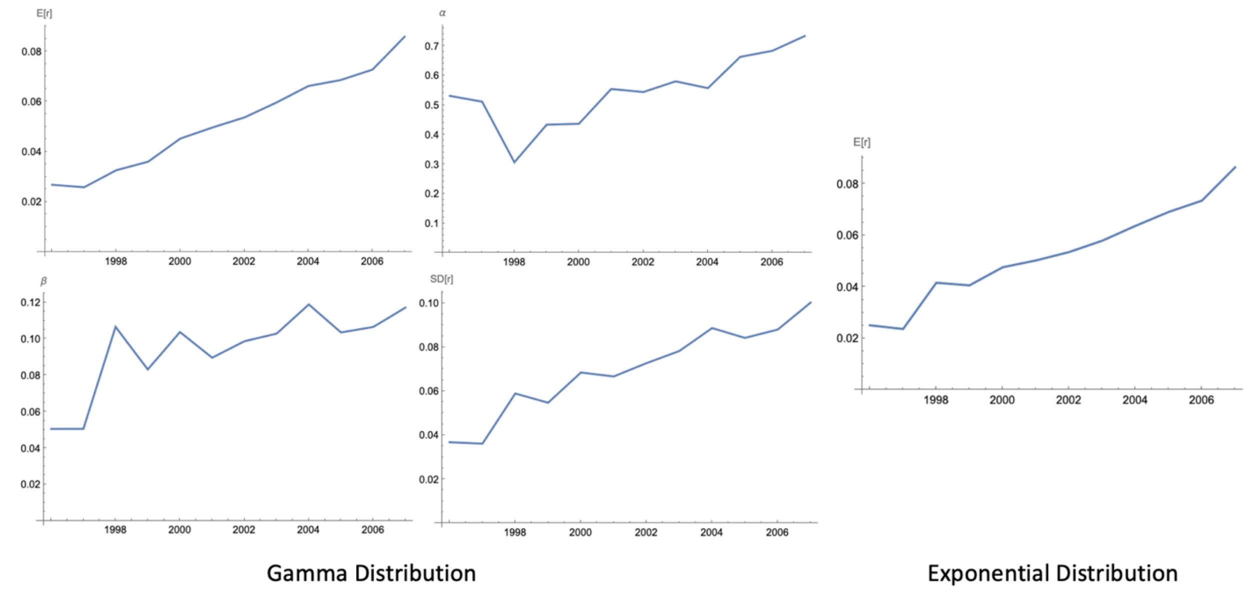

Figure 4: Estimated parameters of the Gamma distribution (left and center) and the exponential distribution (right), 1996–2007.

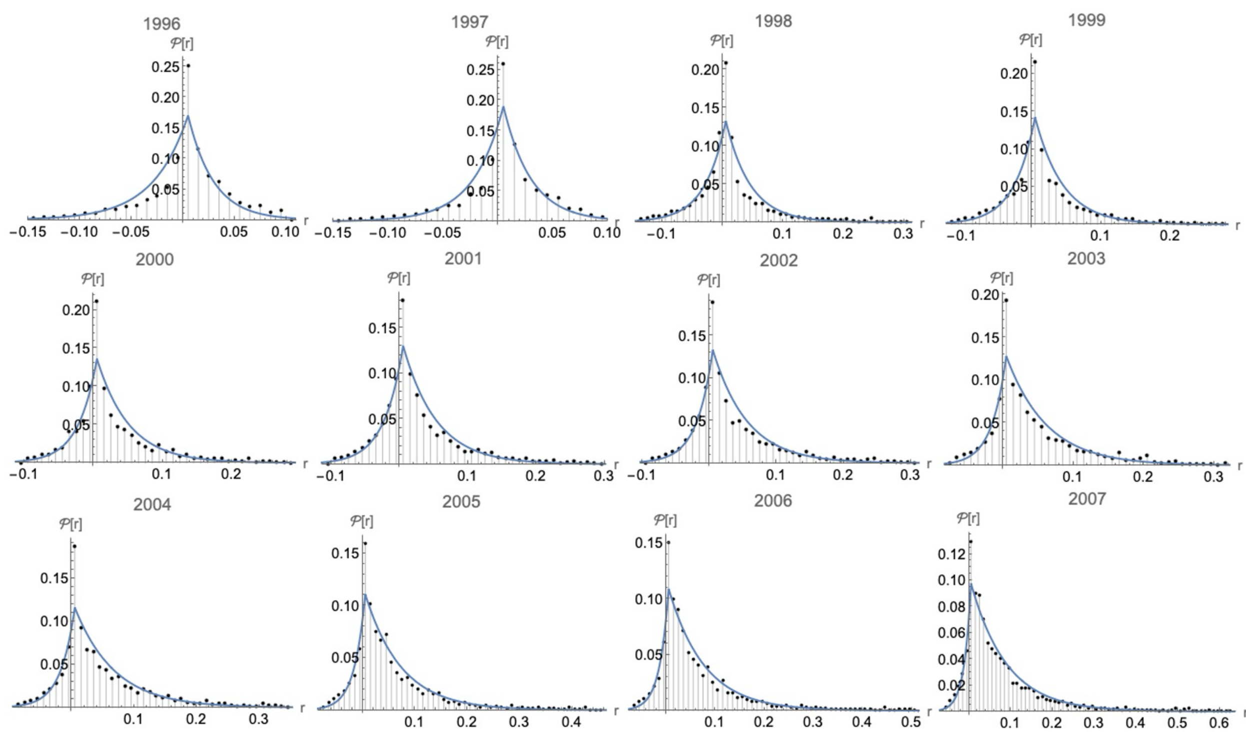

Figure 5: Estimated asymmetric Laplace distribution, 1996–2007.

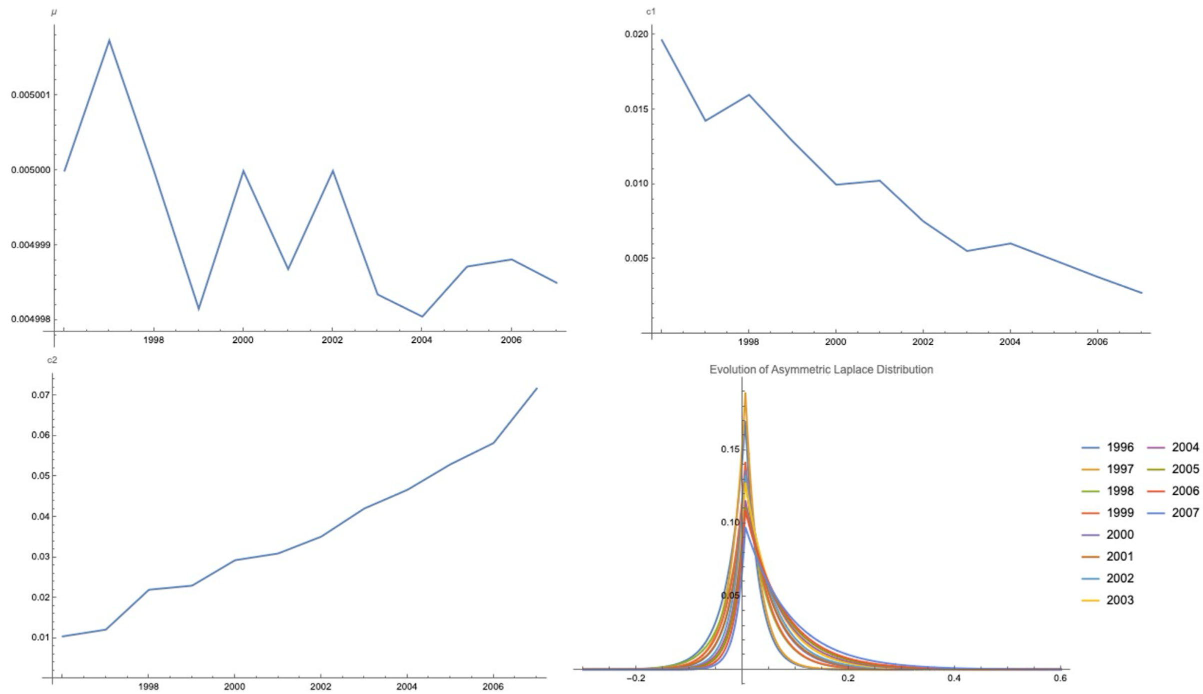

Figure 6: Estimated parameters of the asymmetric Laplace distribution and the evolution of the estimated distribution, 1996–2007.

5.3 QRSE model

Figure 8 shows the estimated QRSE distribution, together with the unweighted empirical distribution and the decomposition of the estimated distribution into the components associated with entry and exit. The model captures the overall shape of the distribution, but its fit is less close than that of the asymmetric Laplace distribution in several years, in particular near the peak of the distribution.

Figure 7 shows the evolution of the estimated parameters. The central tendency α rises steadily, from slightly below zero in 1996–1997 to about 0.08 in 2007, mirroring the rising mean profit rate. The scale parameter S also rises, from about 0.035 to about 0.11, consistent with the widening of the distribution. The tipping point μ is slightly positive in 1996–1997 and slightly negative thereafter, fluctuating between about -0.02 and -0.005. From 1998 onward, then, capitalists are estimated to be more likely to enter than to exit a sector even at slightly negative profit rates. The behavioral temperature T is volatile in the early years and close to zero from 2002 onward, which indicates that entry and exit decisions respond increasingly sharply to whether profit rates lie above or below the tipping point.

5.4 Model comparison

Table 4 reports, for each year, the minimized divergence between the empirical distribution and each estimated model. Two features of the measure affect how these values should be read. First, the divergence is computed between the empirical bin frequencies and the model density evaluated

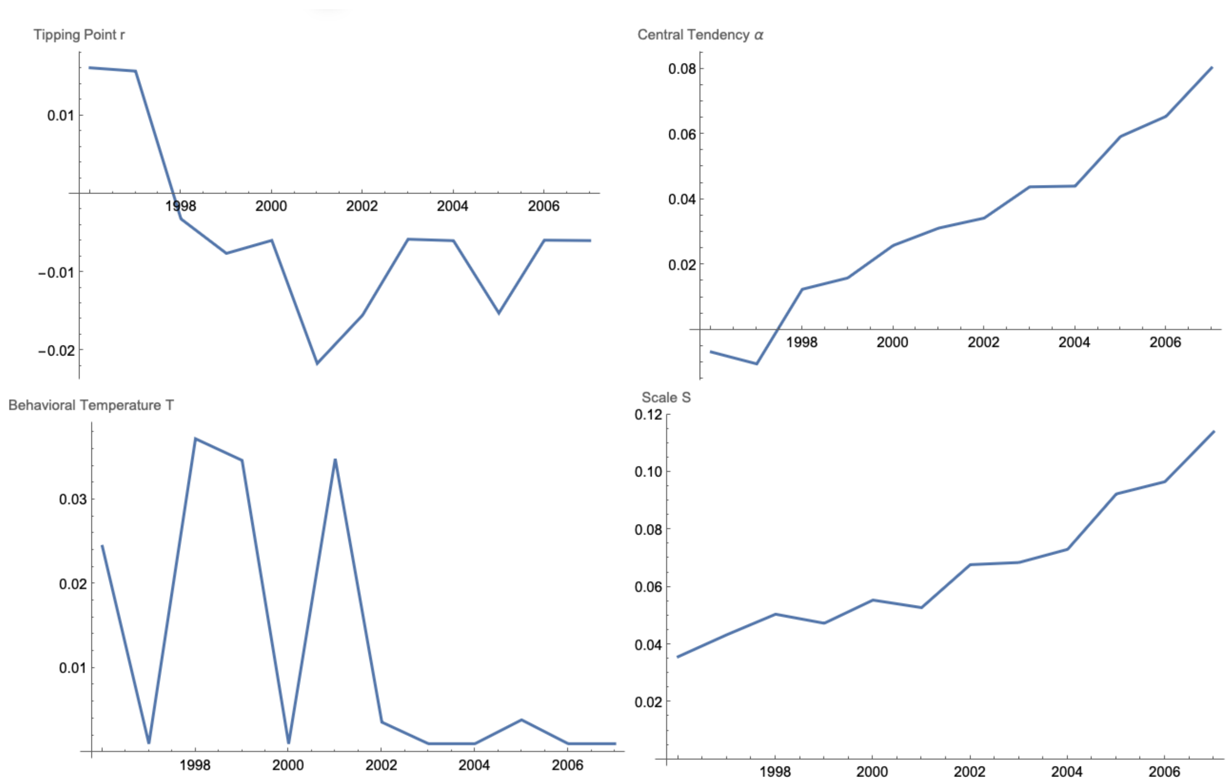

Figure 7: Estimated parameters of the QRSE model, 1996–2007.

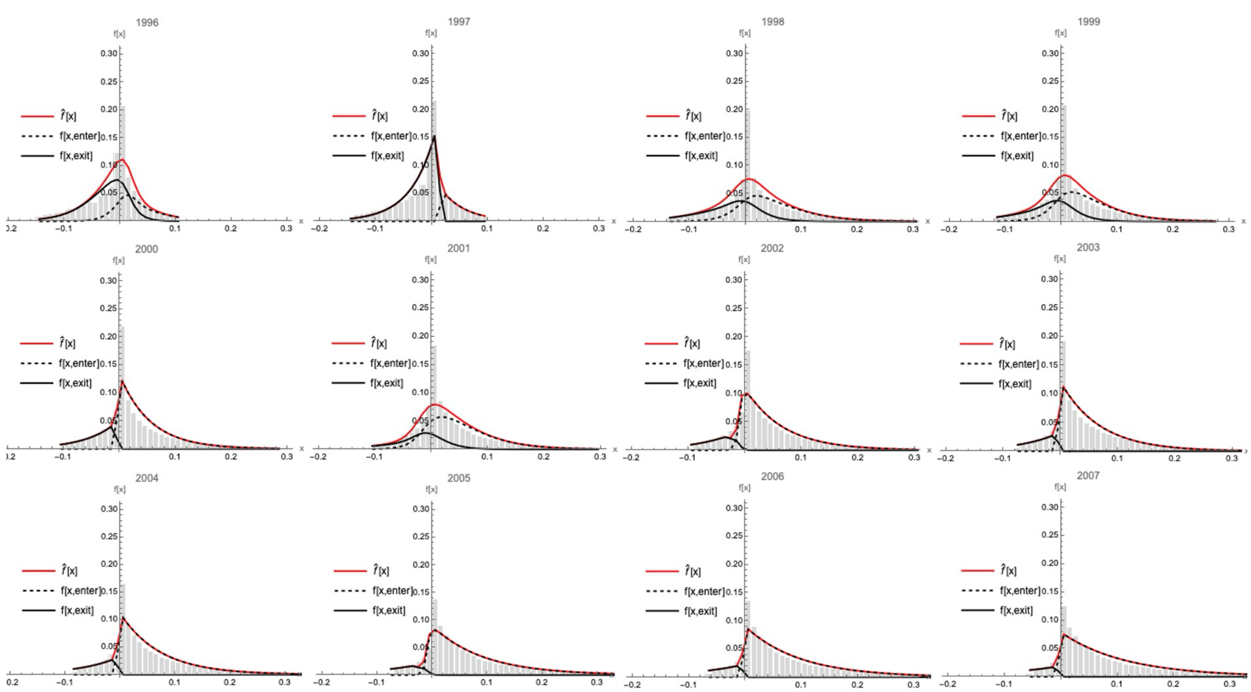

Figure 8: Estimated QRSE distribution, 1996–2007. The red line is the estimated marginal distribution of profit rates; the dashed and solid black lines are the components associated with entry and exit.

at the bin midpoints, rather than between two sets of bin probabilities. Unlike the Kullback–Leibler divergence between two probability distributions, the measure is therefore not bounded below by zero, and its level depends on the bin width, which is why the values for the Gamma, exponential, and QRSE models are negative. Because the bin width is the same in every year, the values remain informative about how the fit of a given model changes over time. Second, the models are fitted to different versions of the data, weighted or unweighted and with or without negative profit rates, so their divergences are not measured against the same empirical distribution. For these reasons, the values in Table 4 should be compared across years within each model rather than across models, and we do not use them to rank the four models. Within each model, the values fall over the period, which indicates that all four models describe the later years more closely than the early ones. Across models, visual inspection of Figures 3–8 suggests that the asymmetric Laplace distribution and the QRSE model, which accommodate negative profit rates, describe the data more closely than the exponential and Gamma distributions. A formal comparison, based on properly normalized divergences computed on a common support or on Bayesian model comparison, is an important task for future work.

Table 4: Divergence measure between the empirical and estimated distributions

Year	Gamma	Exponential	QRSE	Asymmetric Laplace
1996	−3.222	−3.217	−4.529	0.076
1997	−3.252	−3.245	−4.552	0.047
1998	−3.024	−3.015	−4.532	0.097
1999	−3.209	−3.205	−4.560	0.072
2000	−3.391	−3.385	−4.550	0.065
2001	−3.384	−3.381	−4.569	0.064
2002	−3.585	−3.581	−4.567	0.056
2003	−3.819	−3.816	−4.562	0.042
2004	−3.809	−3.803	−4.560	0.047
2005	−3.938	−3.934	−4.568	0.039
2006	−4.023	−4.018	−4.570	0.038
2007	−4.145	−4.141	−4.576	0.045

Note: Minimized value of the divergence used in estimation. The exponential and Gamma distributions are fitted to the capital-weighted distribution of positive profit rates, the asymmetric Laplace distribution to the full capital-weighted distribution, and the QRSE model to the full unweighted distribution. Because the divergence is computed between bin frequencies and model densities, it can take negative values. Values are comparable across years within a model but not across models; see the text.

6 Conclusion

This paper has studied the distribution of firm profit rates in China from a statistical-equilibrium perspective. Drawing on the classical view of competition as a process that tends to equalize profit rates without making them uniform, we fit four maximum-entropy distributions, the exponential, Gamma, asymmetric Laplace, and QRSE distributions, to the annual distribution of profit rates of

Chinese industrial enterprises for 1996–2007.

The profit-rate distribution is sharply peaked and asymmetric, and a substantial share of firms report negative profit rates, which makes models that accommodate both positive and negative profit rates particularly important. The asymmetric Laplace distribution fits the data closely in every year, and the QRSE model captures the overall shape of the distribution. The exponential and Gamma distributions, which apply only to positive profit rates, yield very similar estimates. Over the period, the mean profit rate rises, the lower tail of the distribution contracts, and the upper tail lengthens. These changes suggest that low-profit firms increasingly exited the market while some firms sustained high profit rates, but they cannot be summarized by the mean profit rate alone.

The analysis has several limitations. The sample covers twelve years, which is too short to assess long-run trends in profitability. Trimming the distribution at the 5th and 95th percentiles removes its tails, which are precisely where the candidate distributions differ most, so future estimates should use the full distribution with a model of measurement error or outliers. Finally, the divergences computed here do not provide a valid comparison of the models, since the models are fitted to different versions of the data and the divergences are not computed on a common scale. Future work should fit all models to the same distribution and compare them formally, using divergences computed on a common support or Bayesian model comparison, extend the analysis to longer periods, and apply the same framework to firm-level profit rates and markups in other economies, including the United States.

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