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Scale-free phenomenon in industries in China

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HIGHLIGHTS

- Through investigating the data, we find that there are scale-free phenomena in Chinese industries.
- The phenomena cannot be explained by the existing theory but can by the Simon Model mathematically.
- We discuss the industry network and think it will be helpful for understanding the economic cycle.
- We discuss the forest-fire model and think it is helpful for understanding the dynamics of industries.

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ABSTRACT

In this paper, we investigate the data of industries in China and find that the frequency distributions of fixed assets and fixed-assets' investment of industries obey power laws. We show that these power-law modes can be explained by the rules of the Simon Model, rather than the existing investment theories such as the classical investment theory or acceleration principle. Moreover, the mechanism of the investment distribution may be similar to the forest-fire model of self-organizing criticality. By introducing the complex system methods, this research changes the traditional opinion of the investment and gains some meaningful understanding in the dynamics of industries and the economic cycle.

1. Introduction

The scale-free phenomenon (or the power-law distribution) is widely presented in physics and social sciences [1,2]. Especially in economics, there have been plenty of studies showing that the distributions of city size [3,4], income or wealth [5], firm size [6] and so on obey the power laws, although the origin of which are important issues still being under discussion.

In this paper, the power-law behaviors with exponents of about 2 are observed in the distribution of the fixed assets and the fixed-assets' investment in industries when investigating the data of Chinese industries [7,8], revealing non-random rules working in the dynamics of industries.

In economy, there were a series of theories proposed to explain the investment phenomenon. For example, the classical investment theory assumes that the investment is related to the interest rate, while the acceleration principle and expected profit principle assume that it is determined by output or profit. These theories, which are successful in explaining many

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Table 1
Part of the data come from the second China Economic Census.

Industry	Number of enterprises	Total industrial output (current prices)	Total assets (original price)	Fixed assets	Main business income	Profit	Total wages	Employees (ten thousand)
Mining	589 199	124 654.01	87 720.66	43 240.41	83 570.12	6319.31	5409.23	2542.97
Coal mining and washing	21 317	15 492.33	20 549.51	10 440.10	16 155.02	2660.51	2028.23	572.53
Oil and gas exploration	1 326	10 642.19	12 859.05	14 428.39	11 078.28	4638.31	589.10	115.02
Ferrous metal mining	16 872	4 264.50	3 714.51	1 534.53	4 114.86	823.76	222.63	95.55
Non-ferrous metal mining	10 191	2 945.91	2 764.33	1 270.63	2 902.01	468.34	175.30	75.75
Non-metallic minerals	43 838	2 851.32	2 124.90	1 359.79	2 765.94	338.13	241.49	132.81
Manufacturing	180 257	38 763.88	28 652.33	13 673.97	37 436.60	2485.11	3188.80	1486.96
Agro-food processing	99 799	26 010.28	12 753.20	6 494.07	25 583.51	1721.67	922.56	461.30
Food	40 338	8 466.26	6 059.49	3 227.60	8 175.79	645.09	491.74	219.07
Beverage	33 856	6 824.13	6 687.64	3 523.12	6 679.87	657.59	387.02	165.47
Tobacco	236	4 491.97	4 433.01	1 509.76	4 262.67	696.36	166.84	20.01
Textile	103 983	23 417.72	17 278.34	9 248.14	22 704.76	1164.81	1687.07	825.01
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of the phenomena of investment, however, have failed to explain the scale-free phenomenon in our statistics; thus a new approach and perspective are required to understand the scale-free mechanism.

On the other hand, the complex system science is becoming a popular research paradigm, which can be used to study various complex phenomena (such as scaling) in nature and society through building complex-network models, adopting computer simulation or mathematical analysis and so on. As a typical complex system, the economic system can be modeled by a complex industry network in the way of input–output [9], and also in the following sections, an analogy between the industry network and the forest fire is proposed [10,11].

Adopting a new assumption and imitating the rules of the Simon Model [1], we can explain the origin of this distribution in mathematics. In short, the complex system method and mathematical analysis are helpful to understand the nature of the fixed assets' investment and the economic cycle.

2. Empirical statistics

The data we analyzed are from the website of National Bureau of Statistics of China. They consist of two datasets, the National Annual Statistical Bulletin and the second China Economic Census (2008) (part of them are shown in Tables 1 and 2). National Annual Statistical Bulletin records the fixed assets' investment in various industries and industries roughly divided into about 34 sections (even less in 2012). On the contrary, in the second China Economic Census, industries are divided into about 454 sections and the information is recorded in much more detail including fixed assets, profit, income, the number of employees, and so on [7,8]. Due to lack of fidelity, some industries recorded in the second China Economic Census that are too small or too difficult to classify are excluded when processing the data. For example, the precious metals' mining, including gold mining, silver mining and other precious metals' mining. However the scale of other precious metals mining is much smaller than gold and silver mining. Thus we will ignore the date of other precious metals mining in processing.

The cumulative frequency distribution of fixed assets of the secondary industries is shown in Fig. 1, while that of wholesale and retail industries are shown in Fig. 2. Besides, the cumulative distributions of the frequency of fixed assets' investment are shown in Fig. 3. We can see from Fig. 3 that the fixed assets' investment of top 6 large-scale industries is more than 1 trillion in 2012 and they are mining, manufacturing, real estate and transportation, etc. (Table 2).

As shown in Figs. 1–3, the slope of the cumulative distributions are −1.06 (Fig. 1) and about −1.09 (Fig. 3), respectively, suggesting a power-law exponent of 2.06 for the frequency distribution of the scale of fixed assets as well as 2.09 for the fixed-assets' investment. These power-law behaviors show that the fixed-assets' investment is guided by certain internal rules. Next we will explain the origin of these distributions with the Simon Model [1] and discuss the underground physical mechanism by the forest-fire model [11].

3. Mathematical analysis

In the paper about the long-tail distribution and the mechanism of power law [1], Newman lists a variety of representative models and attaches great importance to the Simon Model [1,12]. The Simon Model was built to explain the distribution of frequency of words in text, whose basic assumption is 'the richer are getting richer'. Here, we think that such a mechanism