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Measurement of the New Economy in China: Big Data Approach

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1. Introduction

After more than three decades of rapid economic growth, China has entered a "new normal" stage in which economic growth has appeared to slow down. Demand for exports decreased sharply after the 2008 financial crisis. The after-tax return to capital was about 12 percent before 2005 (Bai, Hsieh, and Qian 2006), but it dropped to 4.17 percent in 2013 (Bai and Zhang 2014).[3] In terms of labor, Cai and Wang (2005) estimated that the demographic dividend contributed 26.8 percent to the growth of per capita gross domestic product (GDP) during 1982 to 2000, and warned that such a demographic dividend would disappear after 2013. Cai (2008a, 2008b, 2010) asserted that the Lewis turning point has indeed arrived, which implies that labor supply is no longer unlimited (Lewis 1972). To make things worse, China is "aging before affluence": in 2000, China's per capita gross national income was only 17.3 percent of the world average, but it is projected that the proportion of those ages 60 and over will increase from 10 percent of the population in 2000 to about 30 percent in 2050 (Cai 2010).

China is not alone in experiencing economic slowdown after a long period of high growth. The United States experienced an economic slowdown beginning in 1972 after a nearly 25-year period of unprecedented growth. However, around 1995, U.S. economic growth accelerated, mostly driven by faster productivity growth characterized by thriving information technology (Gordon, 2000). Although there is increasing speculation about whether China's growth is losing its source and momentum, the country's economic potential is probably underestimated, as some promising factors have been less documented. For example, China is continuously accumulating human capital. According to the 2010 census, the average level of education of workers ages 25 and older is 11.8 years (calculated from the 2010 census),

[3] Bai, Hsieh, and Qian (2006) used fixed capital formation as the basis for capital (thus excluding inventory from capital) and GDP net of labor income as the basis for capital income (thus including all taxes on businesses in capital income). In producing the estimation of the real return to capital in 2013, Bai and Zhang (2014) adjusted capital by including inventory, capital income by excluding all taxes on businesses, and capital and income by excluding the residential housing sector.

a 2.5-year increase from two decades ago (1990 census). By studying patent patterns, Xie and Zhang (2016) showed that China's ability in innovation has greatly improved. The number of patents filed has been the largest in the world since 2011. Enterprises filed 16 percent of the country's patents in 1985; by 2009, they had filed 49 percent. In particular, 75 percent of invention patents are filed by enterprises. Therefore, enterprises already account for the majority of patent applications.

The better quality of labor and increased innovative abilities of enterprises provide the foundation for the prosperity of the new economy sector. It is hoped that the new economy sector will serve as a new engine for China's further growth. How large is the new economy sector? What is the future growth trend of this sector? Will the sector be able to provide sufficient employment opportunities? The answers to these questions are of critical importance for confidence in China's growth potential. However, partly because of the lack of a clear definition of "new," official statistics cannot provide timely answers to these questions.

To attempt to fill this void, we have constructed an index that tracks the size and change of the new economy sector in China. Because of the lack of official data, we rely on data collected from the Internet to gauge the share of the new economy sector in the total economy. Sub-indexes for capital, labor, and technology were also constructed and are reported herein.

The next section describes the scope of the new economy and the method used to identify new economy enterprises. Section 3 presents the construction of the New Economy Index (NEI). Section 4 uses the NEI to describe patterns in the new economy sector in China since August 2015 and the NEI's relationship with other indexes. Section 5 provides policy implications and conclusions.

2. Classification of the New Economy Sector with the Big Data Approach

Scope of the New Economy Sector

Construction of the NEI first required defining the scope of the new economy sector in China. For the United States, the new economy has been described as the result of the transition from a manufacturing-based economy to a service-based economy. Starting in 2008, the think tank Information Technology and Innovation Foundation has been producing the State New Economy Index to measure the new economy in U.S. states. Based on international experiences and observations about China, we define an industry as belonging to the new economy sector if it satisfies the following standards.

First, an industry is considered to be in the new economy sector if it is human capital intensive, technology intensive, and has a ratio of fixed capital that is relatively low. We use the Industry Input-Output Table for 2010 and the Sixth Economics Census data to identify industries satisfying these standards. We consider an industry to be human capital intensive if the sum of labor income and operating surplus is more than 70 percent of value added, the average level of education is more than 12 years, and the share of research and development (R&D) is among the top 10 percent in the industry.

Second, new economy industries are those that are in accordance with the country's industrial policies. In recent years, China has issued a series of documents to provide guidance for industrial development, including *Guidance for Accelerating the Development of High-Tech Service Industries*, issued by the State Council in 2011; *Decision to Accelerate the Cultivation and Development of Strategic Emerging Industries*, released in 2012; and *Made in China 2025*, released in 2015.

Based on these standards, we identified nine industries with 111 sub-industries in the scope of the new economy. These are energy conservation and environmental protection, new energy, new energy vehicles, new materials, new information technology and information services, high-tech services and R&D, biological medicine, financial and legal services, and high-tech equipment manufacturing.

Data

Construction of the NEI relies on data obtained from the Internet, which include information on recruiting posts on the Internet, registration information for each new enterprise, information on venture capital investment, bidding, information on New Third Board listed companies, patents and commercialization of patents, and so forth. The data are collected each day and have been combined to calculate the monthly index since August 2015. As of March 2016, the cumulative data in the NEI covered more than 52 million recruitment posts, registration of 2.7 million new enterprises, 3.76 million bids, 28,000 venture investments, 5,000 Third Board listed companies, 5.8 million patent registrations, commercialization of more than 300,000 patents, as well as real-time data on railway tickets and airport flights for calculating urban population mobility. The total storage of raw data amounts to 100 gigabytes (GB), and more than 370 GB of data were generated to calculate the index from August 2015 to February 2016.

As the data are collected from the Internet, the representativeness of the NEI is determined by how information on the Internet reflects real changes in China. To see the relationship of the Internet data with the real data, we can use the data on population mobility as an example. As these data include information on all scheduled flights and train movements, they account for about 74 percent of long-distance travel (at least 200 kilometers) in the country. Another example is data on online recruitment. Each month, all recruiting posts by the major recruitment websites are collected, covering all industries across the nation, with wage offers ranging from 1,000 yuan per month to at least 50,000 yuan per month. To avoid the influence of outliers, the NEI is designed to be based on ratios rather than absolute values. Overall, we expect the NEI to provide a good representation of the development of the new economy in China.

3. Classification of New Economy Industries

Calculation of the NEI first requires identifying whether an enterprise belongs to the new economy sector. The main challenge is that, for each company, the data that are obtained only show the name and scope of operations, but not the sector of the enterprise. When the data are limited, the researcher may infer whether a company is in the new economy sector by checking the company's name and scope of operations, but such brute force practice is unfeasible when judgments need to be performed millions of times. Our strategy is to start with a training sample, identify the algorithm that can best predict the industry that an enterprise belongs to, and then use the algorithm in the full sample.

We therefore classify the enterprise data using the following steps. First, we use the 2.7 million new registered enterprises in 2015 as the training sample to map the business scope of an enterprise with its industry. The path of the mapping is from the scope of business. The position of the enterprise is found in the Product Classification for Statistics, and then mapped with the Standard Industrial Classification Codes. The company's industry is then determined by the number and sequence of key words that are successfully mapped.

For example, when "electronic blood pressure monitor" appears in the business scope of an enterprise, we find industrial code 3584 from the Product Classification for Statistics, which is then mapped into the industry "biomedicine" based on the Standard Industrial Classification catalogue, and then the corresponding four-digit code, 3581, is found. If some items in the business scope can be matched into multiple industries, the exact industry would be identified by weighting these items based on their order of appearance in the business scope. For example, if the business scope of a company includes four items, with the first two items belonging to industry A but the next two belonging to industry B, the company is coded as belonging to industry A, since the first two items that appeared are assigned greater weights then the latter two.

Second, after identifying the industry from the business scope, we segment the names of the enterprises in the sample based on natural language processing. Taking

phrase groups of each company's name as independent variables and the actual industry of each company as the dependent variable, we employ multinomial logit models to establish a model that can best predict the industry from these phrases. To improve efficiency, phrases without industry information, such as "limited" and "corporate," are excluded. Phrases that can predict the industry at least at the 10 percent significance level are kept. We then apply the trained model on the test data. Table 1 compares the error rate in the training data with the error rate in a set of test data. The values in the table show that overall the error rate is low, except in the new energy vehicle industry (over 10 percent), which has few observations in the training data (less than 200).

Table 1. Performance of the Training Model in Training Data and Test Data

	Training data			Test data		
Industry	Actual number	Predicted number	Error rate	Actual number	Predicted number	Error rate
Traditional Economy Sector	257,163	257547	0.1%	231,446	231830	0.2%
New Information and Technology	13,589	13500	-0.7%	12,230	12141	-0.7%
New Materials	338	326	-3.5%	305	293	-3.9%
New Energy	1,354	1399	3.3%	1,218	1263	3.7%
New Energy Vehicles	169	150	-11.3%	152	133	-12.5%
Biological Medicine	3,890	3878	-0.3%	3,501	3489	-0.4%
R&D, Technology Servicies	11,038	10853	-1.7%	9,934	9749	-1.9%
Energy Conservation and Environment	1,757	1739	-1.0%	1,582	1564	-1.2%
Finance and Legal Services	10,011	9926	-0.8%	9,010	8925	-0.9%
Advanced Equipment Manufacturing	620	612	-1.2%	558	550	-1.4%

In the third step, we apply the trained model to the full sample that we have collected for each month. We divide the names of all the enterprises in the full sample with a similar natural language processing procedure. Then we use the model trained in the first two steps to calculate the industrial probability distribution of each enterprise. An enterprise is labeled according to the industry that has the highest predicted

probability. The phrases are updated monthly to maintain prediction accuracy and characterize companies with new innovation.

4. Construction of the New Economy Index

The NEI aims to measure the share of the new economy in the total economy from the perspectives of measuring the relative ratios of labor, capital, and technology innovation. We consider a generalized production function $Y = AK^{w_1}H^{w_2}$, where A is technology, K is capital, H is human capital, and w_1, w_2 is the output elasticity of each input factor. Let θ_i denote the share of each input factor in the new economy. Then the share of the new economy in total output can be calculated as

$$\frac{Y_{new}}{Y} = \frac{(\theta_1 K)^{w_1}(\theta_2 H)^{w_2}(\theta_3 A)}{K^{w_1}H^{w_2}A} = \theta_1^{w_1}\theta_2^{w_2}\theta_3$$

Taking the logarithm on both sides, we obtain

$$ln\frac{Y_{new}}{Y} = w_1 \ln\theta_1 + w_2 \ln\theta_2 + \ln\theta_3$$

Generalizing the production function to include the sub-indexes of labor, capital, and technology, the weight of each sub-index decreases and approximately satisfies the equation without logarithms as the following:

$$\frac{Y_{new}}{Y} = \sum_i \ w_i\theta_i.$$

This equation suggests that we can approximate the share of the new economy by the shares of each factor with appropriate weights. We calibrate the weights based on existing data. For example, the ratio of labor income to total added value of the tertiary industry in 2014 was about 47.2 percent, and it was 49.7 percent in the science and technology industry, but 23.4 percent in the telecommunications industry. Since the main input factor of the new economy is better-educated labor, the weight of labor input is set as 40 percent. The weights of capital (35 percent) and technology (25 perent) are calibrated similarly.

The sub-indexes for better-educated labor input, capital input, and enterprise technology and innovative capacity are summarized in Table 2. In the table, new economy labor input is measured by the ratio of new economy labor relative to labor in all industries, and the ratio of the mean wage offer in new economy industries to the mean wage rate for all industries. Capital is measured from four sub-indexes: the proportion of venture capital investment in new economy industries relative to that in all industries, the proportion of bids in new economy industries to bids in all industries, the ratio of registered capital of new economy enterprises that have applied for the New Third Board to the total registered capital of all enterprises applying for the New Third Board,[4] and technology and innovation. The technology and innovation sub-index is measured by the ratio of scientists and engineers employed by new economy enterprises to total scientists and engineers hired in all industries, proportion of patent applications in new economy industries to those in all industries, and rate of patent commercialization in new economy industries relative to that in all industries.

Table 2. Sub-Indexes of the New Economy Index

Level I indexes	Level II indexes	Interpretation
Labor（40%）	New economy wage offer	Ratio of the mean wage offer in the new economy sector to the total mean wage
	New economy labor demand	Ratio of labor demand in the new economy sector to total labor demand
Capital (35%）	New economy venture capital investment	Rate of venture investment of new economic industries to the total venture investment of all industries
	New economy bids	Ratio of the number of bids of new economy industries on major websites to the total number of bids of all industries

[4] The New Third Board refers to a market platform for share exchanges for tiny, small, and medium size enterprises that are listed neither on the stock exchanges in China (the main board) nor on stock exchanges for small and medium enterprises (the small and medium board).

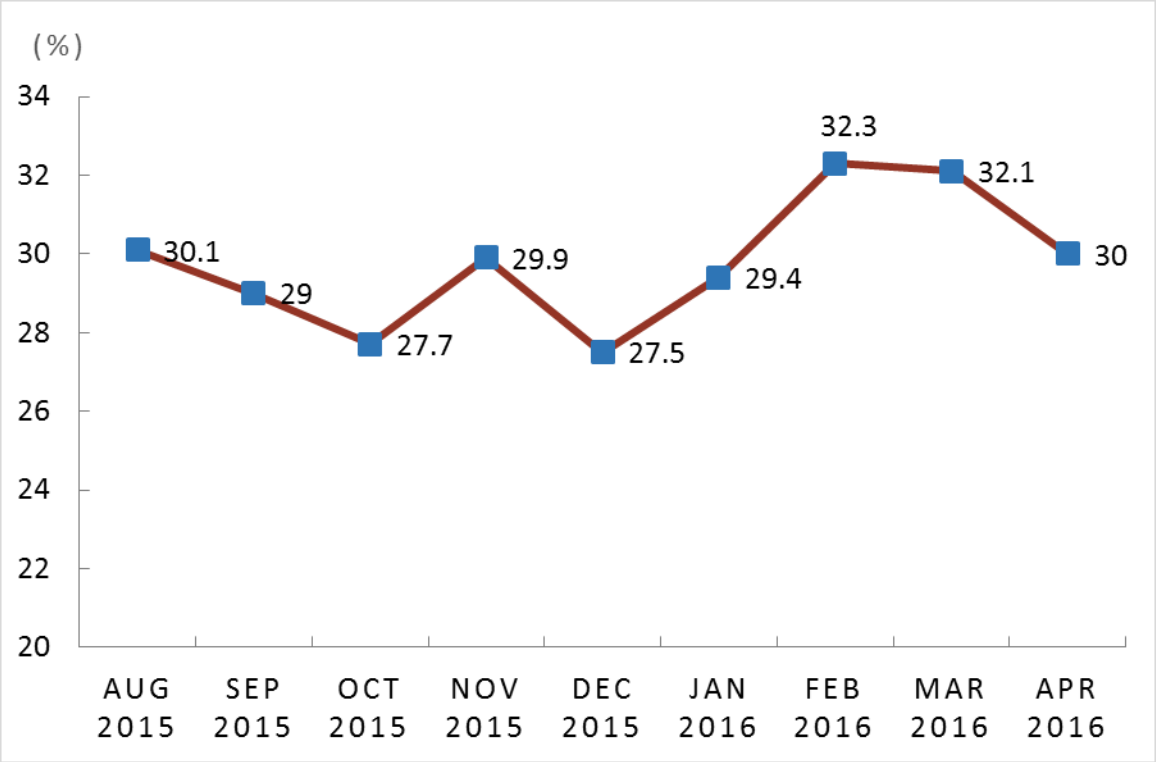
	New Third Board registered capital of new economy enterprises	Rate of registered capital of companies applying for the New Third Board to the total registered capital of all companies in new economy industries
	New economy registered capital ratio	Rate of total registered capital of new companies in new economy industries to the total registered capital of all new companies
Technology innovation (25%）	Scientists and engineers in demand	Ratio of total scientific research personnel to be recruited to the new economy sector to that for all sectors
	Number of patents	Ratio of new patents in the new economy sector to total patents
	Rate of patent commercialization	Ratio of commercialized patents in the new economy sector to total commercialized patents

5. New Economy Index and Current Status of China's New Economy

NEI

Figure 1 presents the NEI of China since August 2015. The figure shows that the share of the new economy sector in GDP increased from about 30.1 percent in August 2015 to 32.3 percent in February 2016, but then dropped to about 30 percent in April 2016, indicating that the new economy sector accounts for about 30 percent of the country's GDP. As the NEI signifies a relative share, the drop may have been the result of recovery in the traditional sector, or slowdown in the new sector. China's macro economy data show that recovery in the traditional sector was the main cause of the recent drop in the NEI.

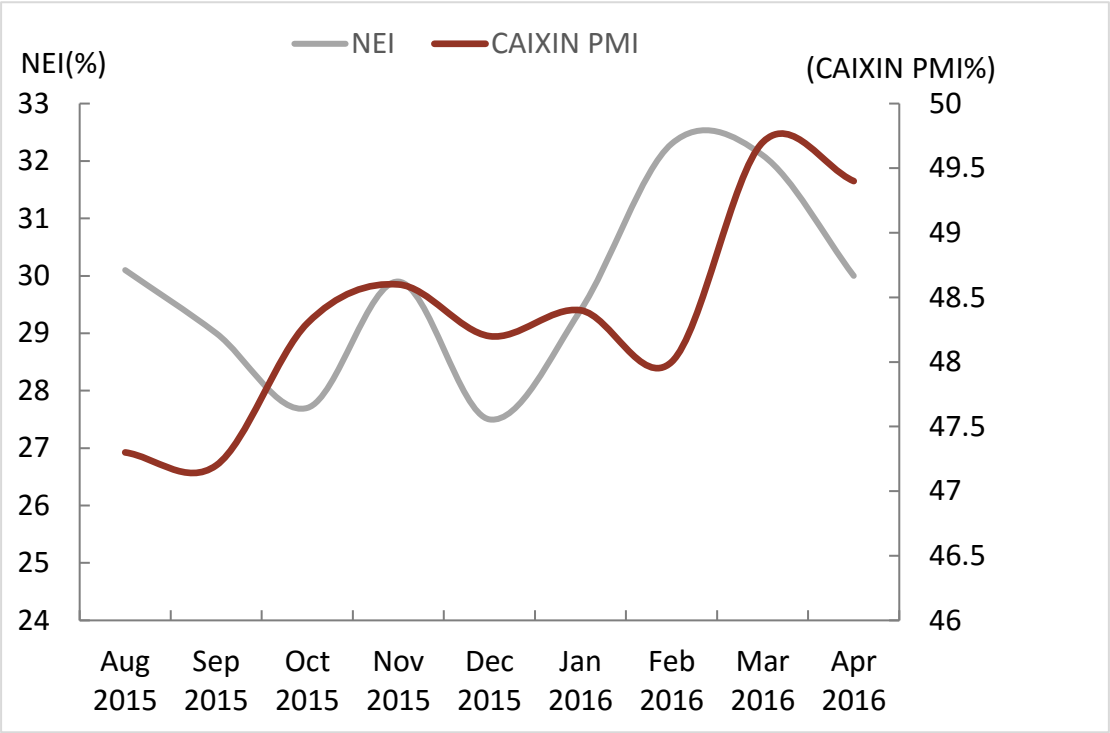
Figure 1. New Economy Index, August 2015 to April 2016



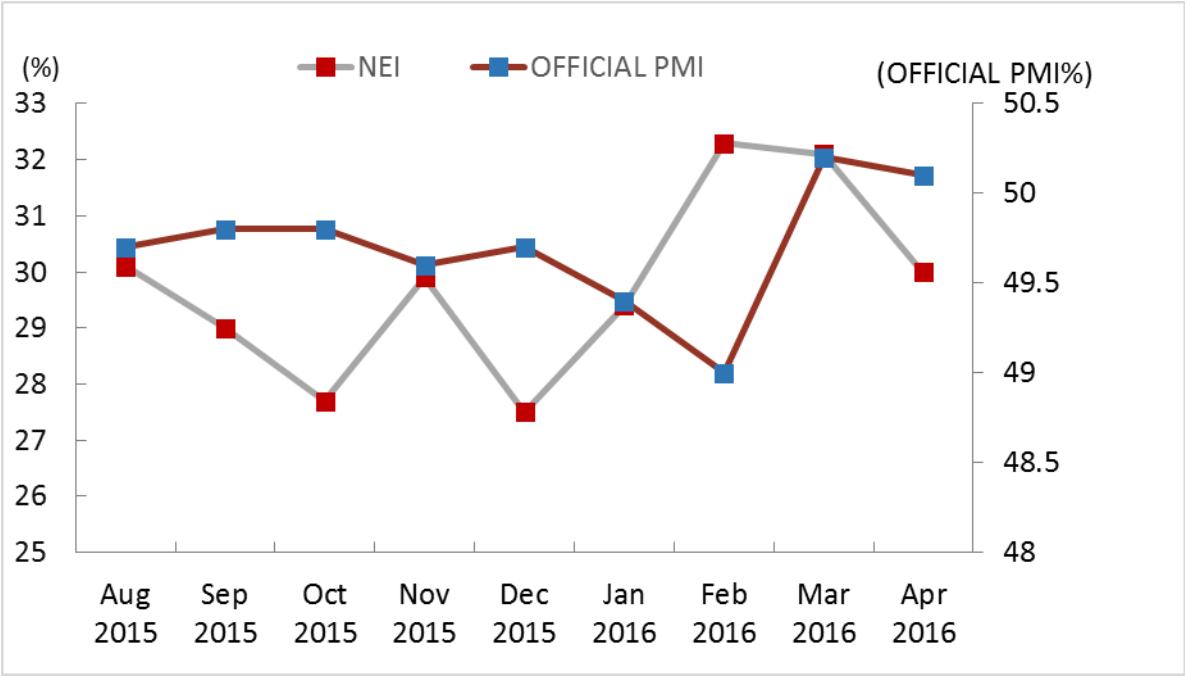
Comparison of the NEI with the Purchasing Manager Index (PMI) of the manufacturing industry illustrates this point. The PMI is constructed based on surveys of representative firms to obtain information on their expectations about the economy. A PMI score lower than 50 indicates a pessimistic attitude toward economic prospects, and a score higher than 50 shows an optimistic attitude. Figure 2, a and b, compares the NEI with two versions of the PMI (Caixin PMI and the Official PMI). In general, there is a negative relationship between the NEI and the PMI, where the recent drop in the NEI coincides with increases in the PMI. As the PMI is dominated by enterprises in the traditional economy sector, it can be considered as better representing the traditional economy. Thus, the negative relationship between the NEI and the PMI is consistent with the observation that recoveries in traditional industries tend to hamper the development of the new sector.

Figure 2. New Economy Index and Purchasing Manager Index

a. NEI and Caixin PMI



b. NEI and Official PMI



NEI Sub-Indexes

The contributions of labor, capital, and technology each have their own characteristics. Table 3 presents monthly changes in the NEI sub-indexes, where the final NEI for each month is obtained by the sum of the sub-indexes multiplied by the corresponding weight. Among the three sub-indexes, labor is the most stable: it was 29.7 in August 2015， fluctuated slightly, and reached 30.9 in April 2016. The capital sub-index is more volatile; it swung between 30 and 38. The technology sub-index has an increasing trend, from 28.1 in August 2015 to 33.5 in April 2016, but with some fluctuations.

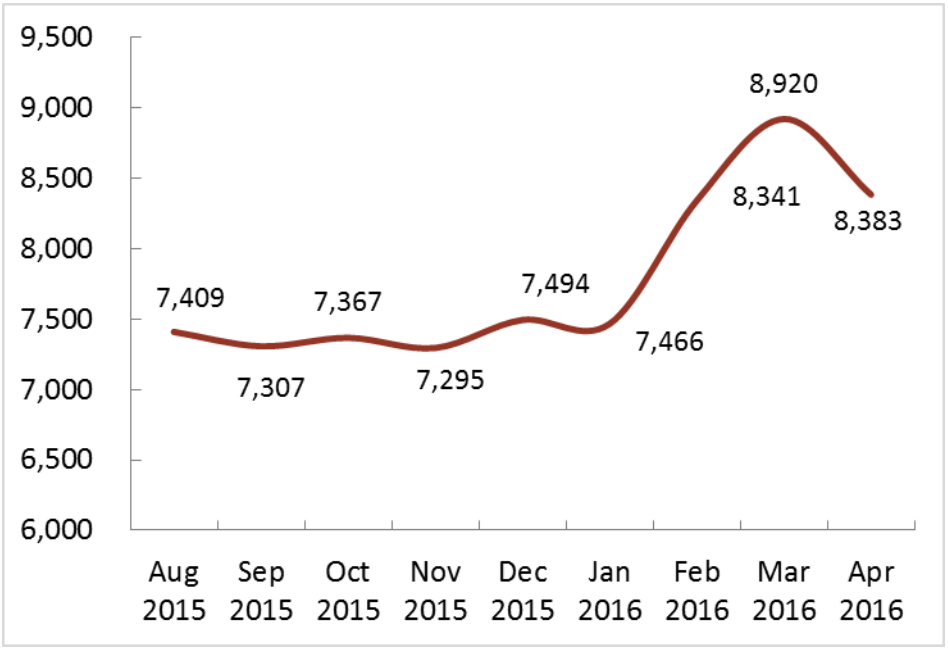
Table 3. NEI Sub-Indexes

Month	Labor	Capital	Technology
August 2015	29.7	32.0	28.1
September 2015	28.1	34.1	23.3
October 2015	28.1	31.5	21.9
November 2015	28.1	37.5	22.2
December 2015	28.0	30.1	23.1
January 2016	28.3	34.5	24.0
February 2016	29.2	38.3	28.8
March 2016	31.4	36.5	27.0
April 2016	30.9	26.6	33.5

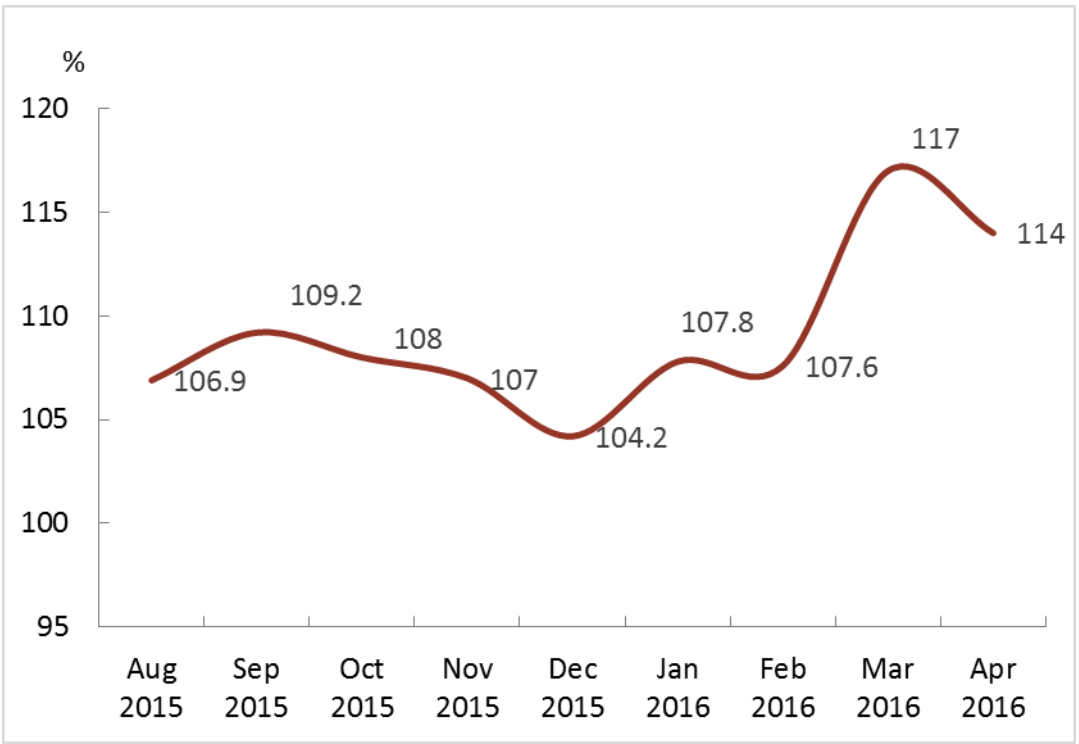
Labor input appears to have an increasing trend since December 2015. Looking closely into new economy labor demand and wages, the data show that labor demand increased from 27 percent in January 2016 to 29 percent in April 2016. The mean wage offer increased from 7,409 yuan in August 2015 to 8,383 yuan in April 2016, an increase of nearly 20 percent (Figure 3a). The gap between the mean wage offer in the new economy sector and the traditional sector has been widening. Figure 3b shows that the NEI mean wage relative to the overall mean wage has increased from 106.9 to 114. The labor sub-index shows that new economy industries recruit labor with higher education, and the sector’s demand for high-quality labor is probably increasing.

Figure 3. Wages

a. NEI wage level



b. Mean NEI wage relative to mean overall wage

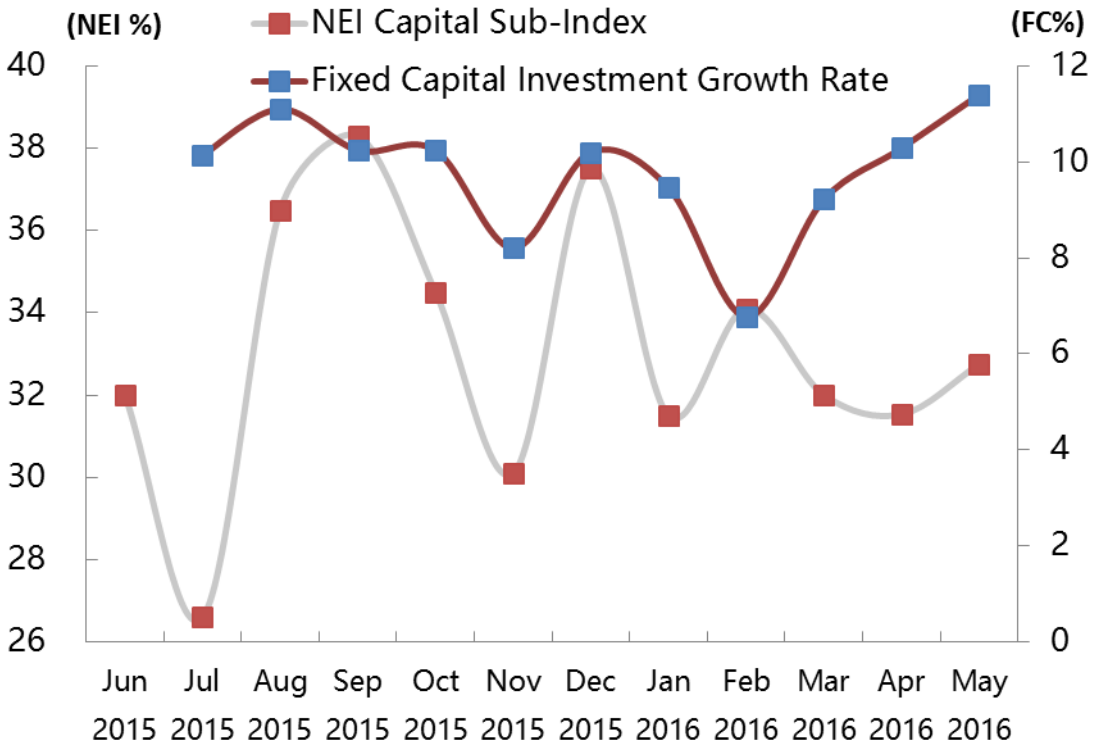


The capital sub-index provides a chance to observe the patterns of capital investment in the new economy sector, and how investment in the new sector is related to that in the traditional sector. Figure 4, a and b, compares the share of fixed capital investment in the new economy sector with two measures of the year-on-year growth rate of fixed capital investment. Figure 4a focuses on total fixed capital investment, and Figure 4b on total fixed capital investment excluding real estate and infrastructure. In Figure 4a, the correlation coefficient of the capital sub-index with the year-on-year growth rate of total fixed capital investment is only 0.006, indicating a very weak link between the two series. When fixed capital investment in real estate and infrastructure is excluded, however, the correlation coefficient increases to 0.65. In 2015, the shares of real estate and infrastructure in fixed capital investment were 23 and 24 percent, respectively.

Figure 4, a and b, provides two messages. First, the NEI capital sub-index mimics the growth rate for fixed capital investment other than real estate and infrastructure, providing a new perspective to document changes in fixed capital investment. Second, the insignificant correlation coefficient including real estate and infrastructure implies that the growth patterns of these two industries are negatively correlated with capital investment observed from the NEI. In other words, the capacity in the traditional sector and that in the new sector show a strong substitution pattern.

Figure 4 NEI Capital sub index growth rate

a. compared with fixed capital investment growth rate



b. compared with fixed capital investment growth rate excluding real estate and infrastructure

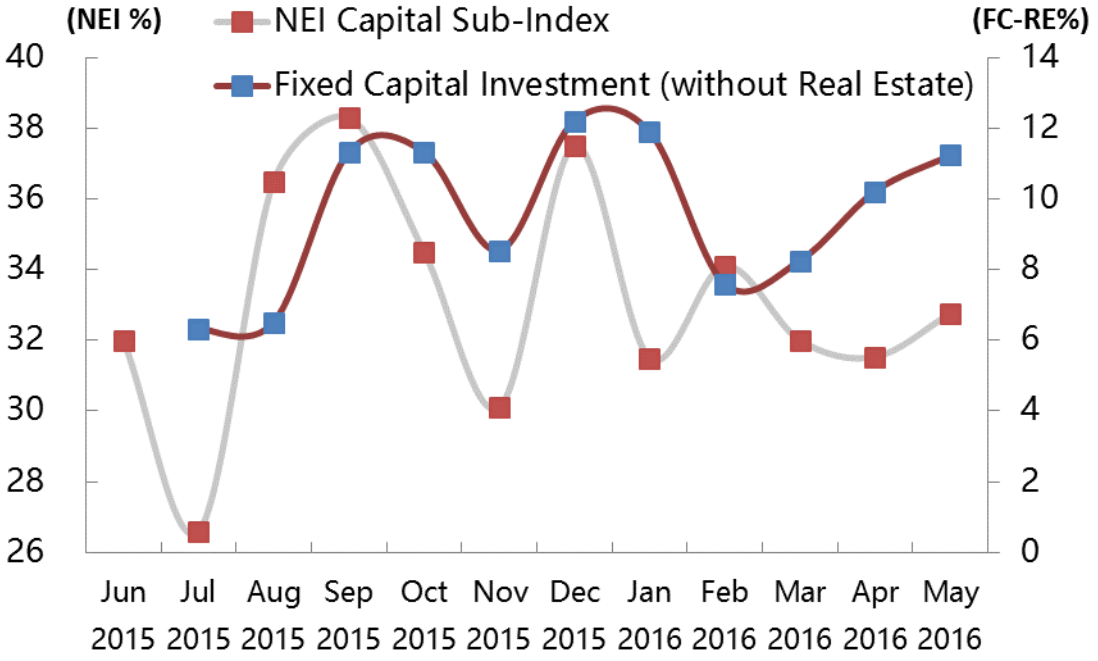
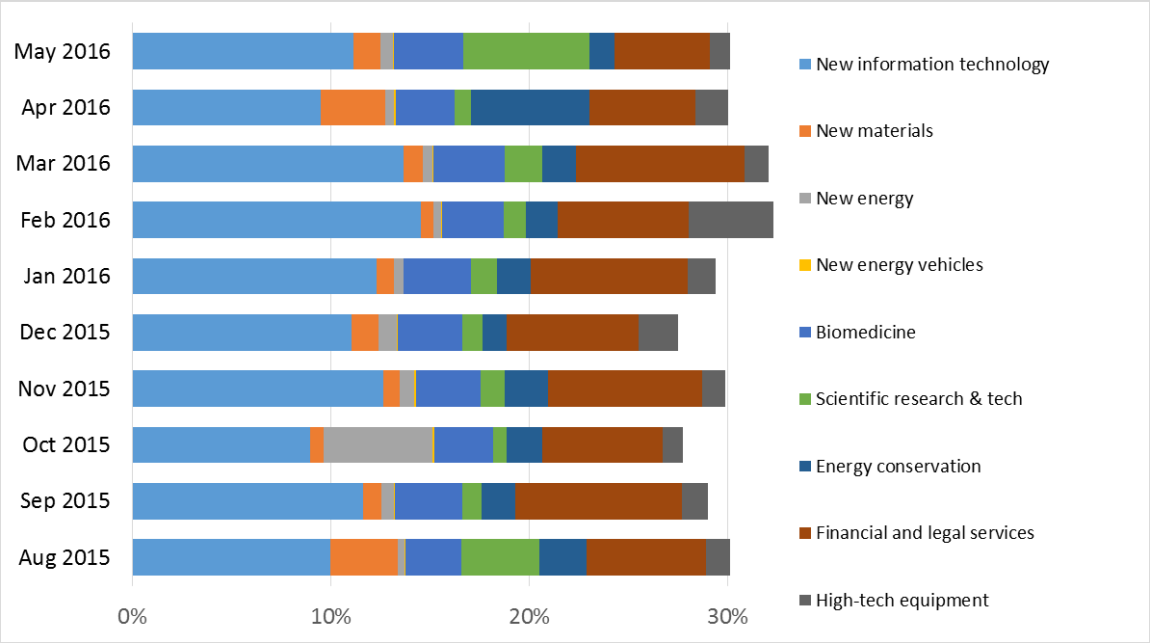


Figure 5 shows the structure of new economy industries. The four largest industries among the nine industries are new information technology and information

services (IT), energy conservation and environmental protection, financial and legal services, and high-tech services and R&D. Although IT has been the largest industry over the past six months, the other industries have switched positions over time. For example, energy conservation and environmental protection has replaced financial and legal services. One reason for this is that as the energy conservation industry is emphasized in the 13th five-year plan in China, investment in this industry has started to increase. The other reason is that to regulate the fast-developing but highly risky Internet finance industry, since April 2016 China has temporarily suspended the registration of new enterprises with "Finance" in the company name. Therefore, the NEI industry composition figure shows that the NEI can mimic these policy changes well.

Figure 5. Shares of New Economy Industries



6. Discussion and Conclusions

China is entering the "new normal" stage with a mix of depressing and promising factors. Although the country's growth rate is slowing, with low returns to capital, increasing labor costs, aging before affluence, and weak global demand, China also

enjoys fast human capital accumulation, increasing abilities in innovation, and increased reflection on the practice of sacrificing the environment for growth. In short, China is at a critical stage of switching from a pattern of high growth rate but low growth quality, to growth with high quality. In such a transition, it is important to document not only the changes in the traditional sectors, but also the new sectors.

This article presented the construction of an index, the NEI, to measure the share of the new economy in China. We defined the new economy sector as having the characteristics of being human capital intensive and technology intensive, and a relatively low ratio of fixed capital; the sector is also consistent with the country's industrial policies. We used big data collected from the Internet and machine learning to help in identifying the new economy enterprises, and then built the NEI level I and level II indexes on these data.

We found that the new economy sector accounts for about one-third of the economy. Comparison of the NEI with indexes for the traditional economy sector showed that the new economy and traditional sectors are negatively correlated. As it is increasingly clear that the traditional sector cannot support sustainable growth, the substitution pattern between the new economy sector and the traditional economy sector implies that, for sustainable growth, China will need to provide more support for the growth of the new economy sector.

Our capital sub-index shows a strong positive correlation with fixed capital investment excluding real estate and infrastructure, but a negative correlation with real estate and infrastructure. This finding implies that the NEI can capture capital investment in the new sector quite well. Policy makers may need to balance carefully the trade-off between relying on the traditional sector to "stabilize growth" in the short run and developing the new sector to gain room for sustainable, long-run, high-quality growth. Rebalancing capital structure through reducing the capacity in the traditional sector, eliminating "zombie enterprises," and increasing investment in the new economy sector can increase efficiency in capital utilization. As development in the

new sector often means explorations of new business models, the market needs to be the determining factor in fostering the environment for the prosperity of the new economy.

The NEI labor sub-index captures the wage offer of the new economy sector and its relative stance compared with those in the traditional sector. An increasing labor demand trend is clearly captured, with increased mean wages, and the gap between the wage offers in the new and traditional sectors is increasing. As the new economy sector mainly recruits labor with better education, its ability to absorb the unemployment released from the traditional sector may be limited.

The NEI is not without limitations. As an index measuring ratios, it reflects the relative changes in the growth pattern of the new economy sector and the traditional sector, but its ability to track long-run changes is limited. And the NEI is built on some strong assumptions. For example, the shares of capital and labor in GDP growth have been set to be identical in the new and traditional sectors. In addition, NEI capital is measured in terms of flow (investment) rather than capital stock; hence, it is assumed that the ratio of capital stock in the new economy sector to that in the traditional sector is similar to the ratio of investment in these two sectors. It would be useful to check these assumptions need to be checked with official data, if such data were available.

Therefore, there is an urgent need for the authorities to put more effort into collecting data in the new economy sector. Such data should be released regularly with reasonable frequency (for example, monthly) so as to help policy makers, entrepreneurs, analysts, and investors track China's economic growth more closely. With more information on the quality of growth (share of the new economy in GDP), the trade-off between the speed and quality of growth can be better understood, and confidence in China's economic transition may be cultivated on more solid ground.

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