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Yuanpeng Cao & Shangze Dai

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Understanding and evaluating new quality productive forces in China: based on machine learning

Yuanpeng Cao^a and Shangze Dai^{b,c}

^aSchool of Government, ECUP, Shanghai, China; ^bFood and Resource Economics Department, University of Florida, Gainesville, FL, USA;

^cWhiting School of Engineering, Johns Hopkins University, Baltimore, MD, USA

ABSTRACT

New Quality Productive Forces (NQPF) is a concept introduced by the Chinese government in November 2023 that has garnered significant interest among scholars. However, a convincing method for quantifying this indicator has yet to be established. This paper first explains the meaning of NQPF and the context in which it was introduced. Then, we define NQPF as the additional increase in green total factor productivity (GTFP) beyond the original growth trajectory. The quantitative method for determining the GTFP growth path employs long short-term memory (LSTM) neural networks. Using this approach, we assess the development level of NQPF across China's first-, second-, and third-level administrative regions from 2010 to 2021. Our findings are intuitive: southeastern coastal regions with advanced digital economies and strong ecological protection have the highest NQPF indices.

KEYWORDS

Sustainable development;
Chinese economy;
transforming economy;
economic growth; NQPF

JEL CLASSIFICATION

E23; O11; O21; O40; R11

I. Introduction

In recent years, the limitations of the traditional concept of productivity have become increasingly apparent (Yu, Dai, and Ke 2024). This conventional view focuses primarily on the input-output relationship between capital and labour, while often overlooking the role of endogenous disruptive innovation in science and technology, as well as the importance of sustainable development. As a result, several extended concepts have been proposed, such as green productivity (Zhou et al. 2024), knowledge production efficiency (F. Fan et al. 2021) and energy total factor productivity (Dai et al. 2024), to more comprehensively capture the influence of technological advancement and environmental sustainability on production efficiency in the modern economy.

Similarly, Chinese government introduced a concept called New Quality Productive Forces (NQPF) in November 2023. It is seen as a innovation concept that departs from traditional economic growth models and productivity development paths (Kroeker 2024). This concept has sparked significant interest. Figure 1 illustrates the fluctuations in the popularity of this keyword

across China's largest search engine (Baidu), social media platform (WeChat), and academic database (CNKI).

Why did the Chinese government introduce this concept at this particular time? How should we understand this new concept proposed by the Chinese government? How can we measure the development level of NQPF? To address these questions, we present the background of this concept in the second section. In the third section, we outline our method for quantifying NQPF. First, we use the non-radial slacks-based measure (SBM) model to calculate green total factor productivity (GTFP). Next, we employ the long short-term memory (LSTM) model in neural networks to predict the growth path of GTFP. Finally, we measure the growth of GTFP beyond its original growth path by taking the ratio of the actual growth to the predicted growth and use this ratio as a quantitative method for NQPF. The fourth section presents the quantitative results for China's first-, second-, and third-level administrative districts from 2010 to 2021. The fifth section offers our conclusions and discussion.

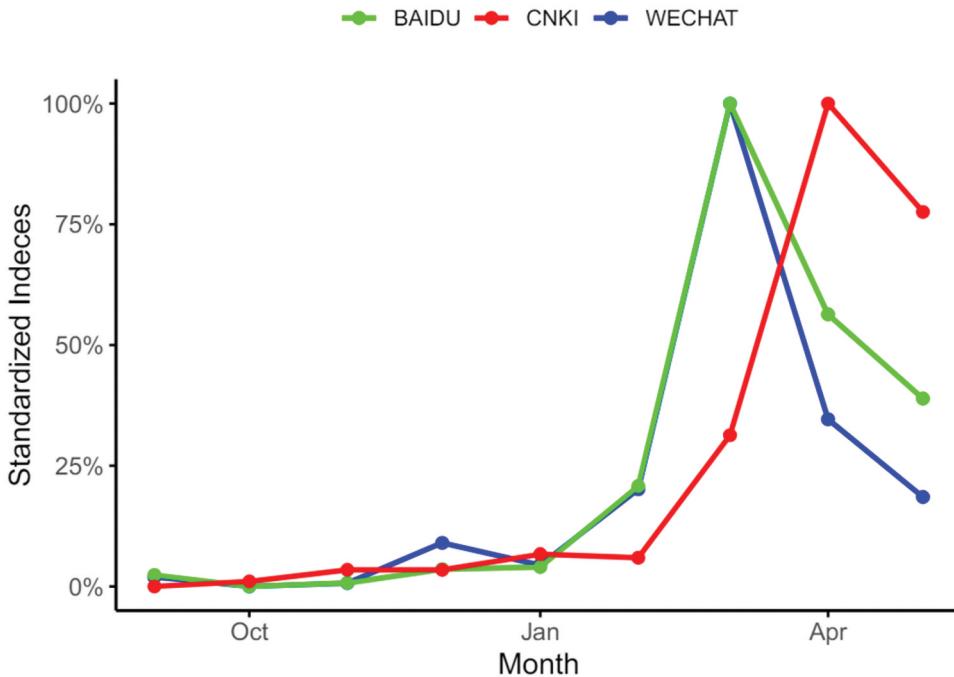


Figure 1. Fluctuations in the popularity of NQPF.

II. Background

After more than 40 years of industrialization and urbanization, the problems inherent in the traditional economic development structure and model have gradually become apparent. By 2011, China's economic growth began to decelerate. In response, the Chinese government started actively promoting innovation and the improvement of total factor productivity (Yu, Dai, and Ke 2024). Nevertheless, China's economic growth rate has continued to slow down, culminating in a nominal GDP growth rate that turned negative in 2023.

The decline in economic growth reflects structural issues in the development and underscores the need to adjust the previous economic strategies. The crux of the problem is that China's past growth, driven by factor inputs, may be unsustainable (Lin and Brueckner 2024). The marginal effects of improving total factor productivity through technological investment are diminishing (Yang, Yang, and Guan 2023). Figure 2 illustrates this situation. In Period 1, rapid economic growth is driven by capital accumulation, improved resource allocation, and rising factor inputs. In Period 2, growth stabilizes as productivity becomes the main driver due to

slower input growth. In Period 3, ageing and environmental constraints lead to stagnant or declining inputs, making productivity gains crucial for sustaining growth. This challenge imposes similar effect to many transitioning economies like Brazil, Malaysia, and Russia (Leach et al. 2021).

To address the current economic development situation (Period 3), the Chinese government has proposed the vigorous development of NQPF. This concept represents the government's exploration of methods to achieve sustainable economic growth. NQPF arises from revolutionary technological breakthroughs, innovative allocation of production factors, and the deep transformation and upgrading of industries (Z. Fan 2024)¹. It is a new type and structure of productivity that has never existed before. Compared with traditional productivity, NQPF boasts higher technical levels, better quality, greater efficiency, and more sustainability.

Therefore, NQPF essentially represents a breakthrough in the mode of production. When considering the ecological environment, the commonly used indicator for measuring productivity development is green total factor productivity (GTFP) (Zhou et al. 2024). Hence, we believe the development level of NQPF can be considered as the

¹Table A1 in the Appendix shows some Chinese officials' definition and description of NQPF..

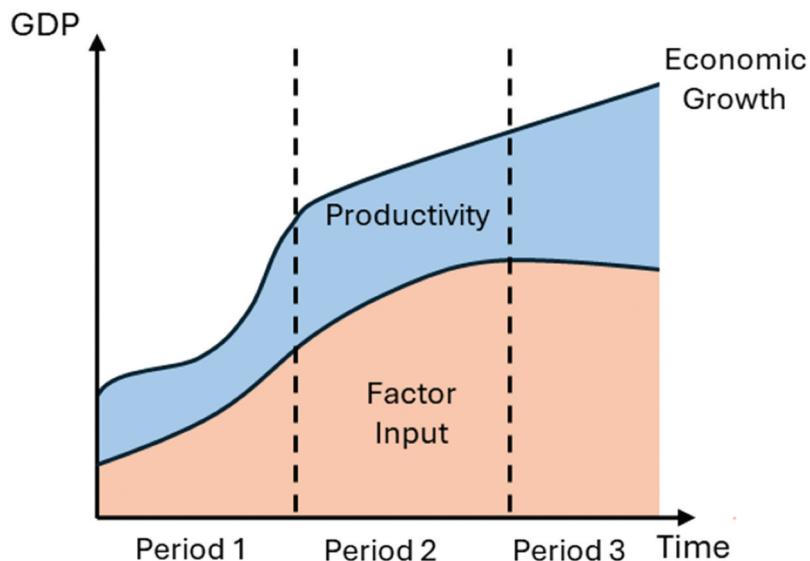


Figure 2. Three periods in economic development.

additional increase in GTFP over its original growth path.

III. The methodology

According to the above, the NQPF can be considered as the unexpected increase of GTFP over its original growth path. We decided first to use the SBM-DEA method² to measure GTFP. Given the positive externalities by agglomeration, we opted for variable returns to scale. This method accounts for both expected and unexpected outputs. We avoided the super-efficiency SBM method due to its computational intensity and susceptibility to extreme values, which is impractical given China's 2,843 third A.D. units.

The input variables are labour and capital, while the output is GDP, and the unexpected outputs are emissions of sulphur dioxide, nitrogen oxides, and smoke. Data sources include the 'China Statistical Yearbook' (first-level A.D.), the 'China City Statistical Yearbook' (second-level A.D.), and the statistical yearbooks of various provinces (third-level A.D.).

After measuring GTFP, we first need to calculate the growth path based on historical values. From there, we calculate the ratio of the actual value to

the predicted value. The larger the ratio, the more it indicates that the growth of GTFP has exceeded the historical path, signifying a higher level of development of NQPF. However, different regions have varying and potential non-linear growth paths due to differences in endowments and transforming situation. Therefore, OLS or time series models are inadequate.

To address these issues, we decided to use the LSTM model. LSTM can capture the time dependencies in sequence data effectively and selectively remember or forget information through forget gates, input gates, and output gates. This selective memory ability allows LSTM to focus on relevant parts of the sequence while ignoring irrelevant information (D'Adamo et al. 2023; Sareen et al. 2023). The structure of this model is illustrated in Figure 3.

Using this model, we can predict GTFP based on the historical data of each region and compare it with the actual GTFP. If the actual GTFP exceeds the prediction, it indicates that the current GTFP has surpassed the historical development path, signifying an improvement in new quality productivity.³ Ultimately, we obtained NQPF data for 31 first-level, 296 second-level, and 2,711 third-level administrative regions in China from 2010 to 2021.³

²The data we used for prediction included data from 1990 to 2009. Therefore, the fitted growth path is mainly based on 1990 to 2009. Comparing the predicted values with the actual values based on the original growth path can largely show whether the original growth path has achieved a breakthrough.

³The complete dataset and the details of corresponding code are available at <https://github.com/RubyDai/New-Quality-Productive-Forces>.

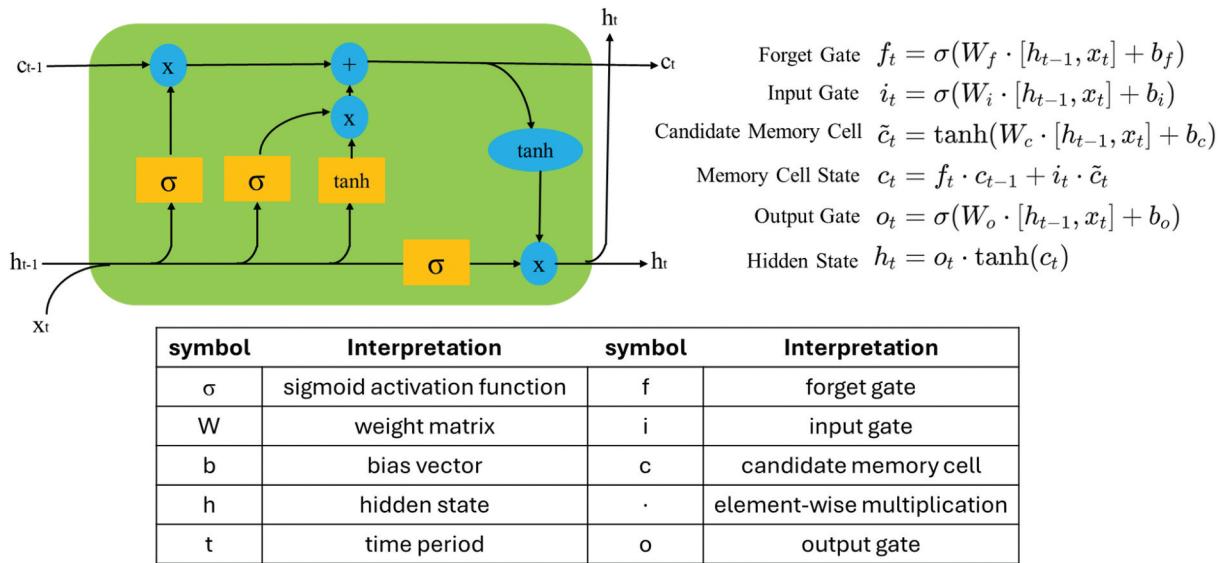


Figure 3. LSTM model structure.

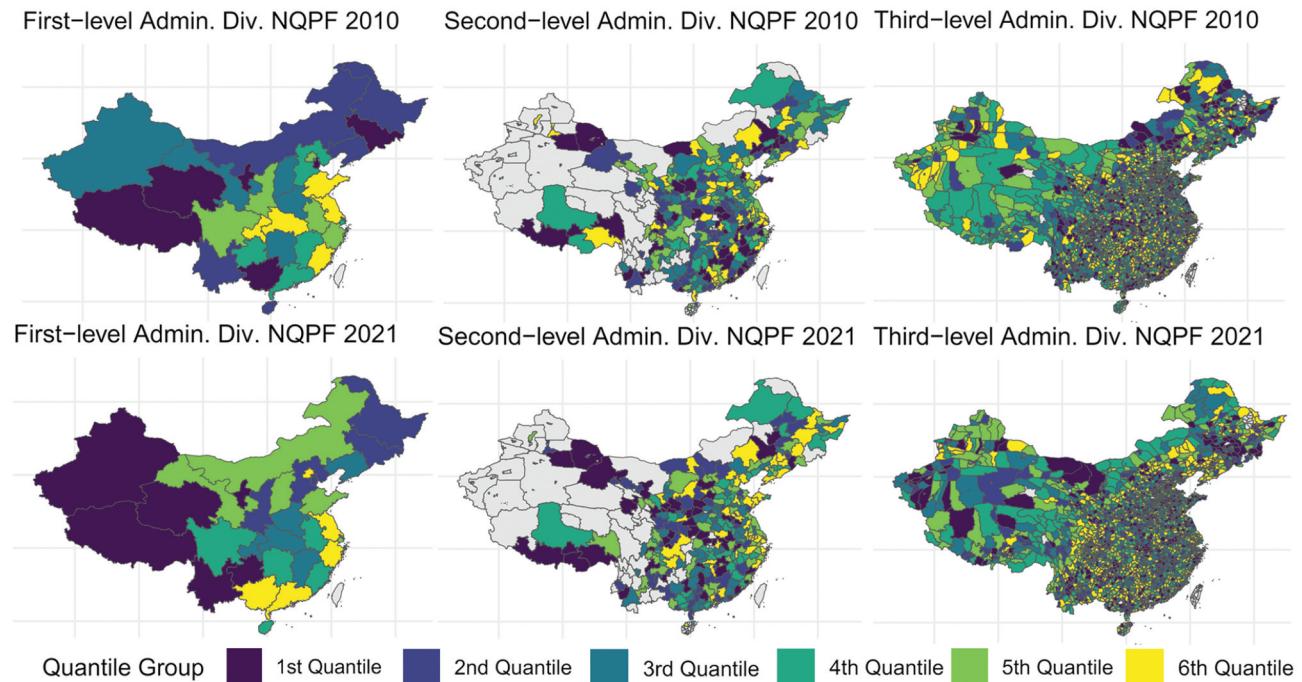


Figure 4. The spatial and temporal distribution of NQPF.

IV. Result

Figure 4 shows the spatial and temporal distribution of NQPF. It reveals that the NQPF is higher in the eastern region and the Yangtze River Basin. This aligns with expectations and recent studies (Zhou et al. 2024), as these areas often have

advanced manufacturing bases, high technology levels, and a strong commitment to ecological and environmental protection. Additionally, there are significant changes in the spatial distribution of NQPF, which may be attributed to the shift in production modes during the digitalization era as

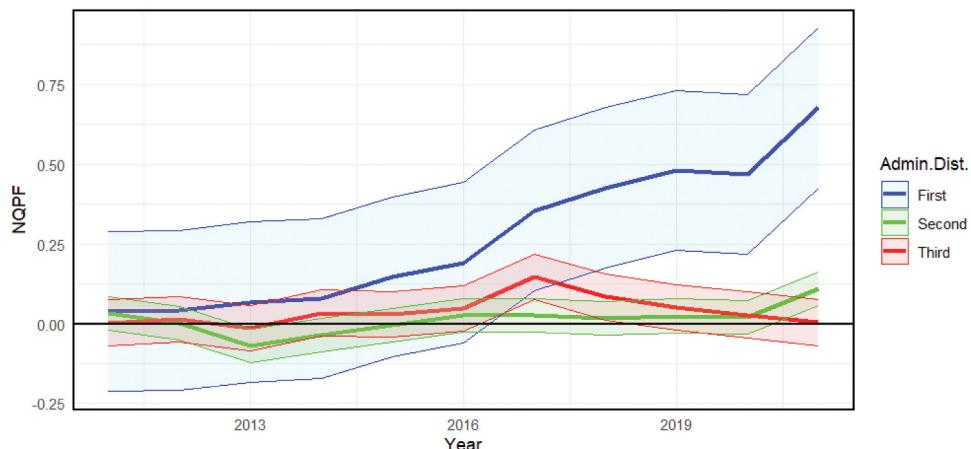


Figure 5. Time trends of NQPF.

indicated in recent studies (Xie, Dong, and Zhang 2024). For instance, NQPF has risen significantly in Zhejiang, Guangdong, and Beijing, home to Alibaba, Tencent, and Baidu, respectively.⁴

Figure 5 presents the time trends of NQPF. While the first level A.D. shows a consistent upward trend, the second and third remain relatively stable. This may be because the time trends represent the average effects across all administrative units. Although the aggregate trend is increasing, there may be divergence when looking at individual units (F. Fan et al. 2021). This divergence likely causes some regions in the second and third tiers to experience growth, while others show a decline.

V. Conclusion and discussion

NQPF, a new concept introduced by the Chinese government, has garnered significant attention from the Chinese academic community. This paper evaluates the development level of NQPF across China's first-, second-, and third-level administrative regions from 2010 to 2021 using the SDM-DEA and LSTM models. The findings indicate that the eastern coastal areas have the highest NQPF values, attributed to their advanced digital economic development and strong ecological protection. This conclusion aligns with expectations and highlights the significant advantages of

these regions in productivity and environmental protection.

While the method used in this paper has certain limitations in measuring absolute size, it effectively compares the relative size of this indicator across different regions under a unified data statistical standard. Transforming economies face environmental and population constraints, making it impossible to achieve economic growth solely by increasing factor inputs. This new concept may provide valuable insights for explaining, measuring, and achieving sustainable economic growth in developing regions.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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⁴In China, Alibaba, Baidu, and Tencent, collectively known as BAT, are three of the most influential and powerful technology companies, each dominating different segments of the tech industry.

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Appendix

Table A1. Some Chinese officials' definition and description of NQPF.

Time	Entity	Content
9/7/2023	President of China	During his inspection in Heilongjiang Province, China, the Chinese President emphasized the need to integrate scientific and technological innovation resources, drive the development of strategic emerging industries and future industries, and accelerate the formation of new quality productivity.
12/11/2023		At a meeting, the Chinese President stated: 'We should promote industrial innovation through scientific and technological advancements, particularly by leveraging disruptive and cutting-edge technologies to create new industries, new models, new momentum, and foster new quality productivity'.
1/31/2024		At the 11th study session of the Political Bureau of the CPC Central Committee, the Chinese President emphasized that 'high-quality development requires the guidance of new productivity theories. In practice, new productivity has emerged, demonstrating a strong driving force and support for high-quality development. We need to summarize and generalize this theoretically to guide new development practices'.
3/5/2024		At the deliberation of the Jiangsu delegation during the Second Session of the 14th National People's Congress of China, the Chinese President stated: 'We must firmly grasp the primary task of high-quality development and cultivate new quality productivity according to local conditions'. He emphasized that developing new quality productivity involves transforming and upgrading traditional industries with new technologies, while actively promoting the high-end, intelligent, and green development of industries.
3/5/2024	Prime Minister of China	The Chinese Premier proposed the development of new quality productivity by 'fully leveraging the leading role of innovation, promoting industrial innovation through scientific and technological advancements, accelerating new industrialization, improving total factor productivity, continuously creating new momentum and competitive advantages for development, and fostering a new leap in social productivity'.
3/24/2024	Director of National Development and Reform Commission of China	At the 2024 Annual Meeting of the China Development Forum, the director of the National Development and Reform Commission of China stated, 'As a crucial driver of global economic growth, China is actively cultivating and developing new quality productivity. This will not only propel China's own development but also provide stronger impetus to the recovery and growth of the world economy'.
3/24/2024	Minister of Finance of China	At the special seminar on the momentum and prospects of China's sustainable development during the 2024 Annual Meeting of the China Development Forum, the Chinese Minister of Finance emphasized the need to coordinate the upgrading of traditional industries, the development of emerging industries, and the cultivation of future industries. He stressed the importance of developing new quality productivity tailored to local conditions.
3/27/2024	Dean of the Institute of New Structural Economics	At the 2024 Bo'ao Annual Conference, the dean of the Institute of New Structural Economics at Peking University remarked, 'China not only holds advantages in the new economy but also possesses significant strengths in catching up within the traditional economy. By effectively leveraging our talent pool, market scale, industrial support systems, and local comparative advantages, and by fostering technological innovation and industrial upgrading, we can develop what is known as new quality productivity'.
6/3/2024	President of Chinese Academy of Macroeconomic Research	The president of the Chinese Academy of Macroeconomic Research asserts that the development of new quality productivity necessitates exploration in five key areas: scientific and technological innovation, industrial development, green development, the reform of production relations, and talent cultivation.
6/13/2024	Vice Chairman of the Central Committee of the Revolutionary Committee of the Chinese KMT	The Vice Chairman of the Central Committee of the Revolutionary Committee of the Chinese KMT believes that developing new quality productivity requires accelerating the transformation of scientific and technological achievements in key areas, making significant breakthroughs in digital technology, promoting the deep integration of digital technology with the real economy, and building a green, low-carbon circular economic system.