Evaluation of Digital Economy Growth: the Validity of the Data Envelopment Analysis (DEA) Method

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A R T I C L E I N F O

A B S T R A C T

This research aims to provide methodological insights that can be used in related studies, as well as offer guidance for the development and improvement of urban digital economies. Gross Domestic Product (GDP)-based scale measurement methods and input-output methods show significant variations in the measurement of digitalisation and the contribution of the digital economy. While index techniques offer convenience in the calculation and expansion of indicators, their accuracy and scientific validity are often in doubt due to subjectivity in the weighting and selection of indicators. DEA offers great flexibility by allocating input and output weights endogenously, reducing the influence of subjectivity. DEA is able to identify fast-growing cities in the digital economy, assess effectiveness, and provide strong support for managerial decision-making, as well as provide guidance for the development of smarter and more efficient cities in the future. This research makes a practical contribution to the development of more appropriate and effective digital economy policies and strategies.

INTRODUCTION

The G20 Digital Economy Development and Cooperation Initiative adopted at the 2016 Hangzhou Summit is an important milestone in the G20 innovation growth roadmap (Liu, Tian, et al., 2024). The digital economy is now the main driver of modern economic development with a focus on deep integration of digital technologies with the real economy, supporting the development of digital infrastructure, improving the governance structure of the digital economy, and supporting the transformation and upgrading of traditional industries (Ghimire et al., 2024; Song & Jiang, 2024; Xiao et al., 2024). The initiative also seeks to develop new industries, formats and models, and continuously expand, upgrade and strengthen the digital economy in cities (Dian et al., 2024; Liu, Xie, et al., 2024). However, the digital economy in cities still faces challenges due to its relatively small size and lack of strength. Therefore, research on the superior growth of the digital economy is becoming increasingly important in the modern era, especially at the urban level.

However, there is an important problem to be solved: how to measure the development of urban digital economy from a scientific point of view (Lin & Zhou, 2024; Smolinski, 2024). This research aims to review the benefits and drawbacks of commonly used metrics in measuring digital economy growth on a national and global scale (Xue et al., 2022). Furthermore, this article delves deeper into the scientific validity of using Data Envelopment Analysis (DEA) to measure the level of digital economic development in cities, as well as offering methodological insights for related studies.

Measuring the production value of the digital economy using the Gross Domestic Product (GDP) measurement principle is known as the "scale measurement method." Therefore, the production method and the expenditure method are the main approaches that can be applied (Ren et al., 2022). Some organisations with industry-representative researchers, such as the Academy of Information and Communication Technology, Tencent Research Institute, and the United States Bureau of Economic Analysis, have used the input-output approach to measure the degree of digitalisation of industries and the digital economy, as well as the contribution of Information and Communication Technology (ICT) to the value added of other economic sectors (Arnold, 2023; Balsalobre-Lorente et al., 2023). The level and scope of development can be reflected directly in this scale measurement approach, which is also capable of calculating the share of Gross Domestic Product (GDP). Its ability to examine the development of the digital economy across different businesses is another benefit (Gaglio et al., 2022). However, the disadvantages of this approach include difficulties in comparing and evaluating due to different domestic and international product classification rules for the digital economy. In addition, data may not be available for new types of digital economy (Shahidi Hamedani et al., 2024). While useful for examining the development of the digital economy, this method is difficult to compare due to differences in product classification rules and limited data for new types of digital economy.

The term "index method" refers to the process of selecting a number of indicators related to the digital economy, building a comprehensive indicator system, and using quantitative indicators to show the development level of the digital economy in (Dian et al., 2024; Ge et al., 2024). When assessing the growth rate of the digital economy at the urban level, benchmarks can be divided into categories such as innovation, coordination, openness, sustainability, and inclusiveness (Liu, Xie, et al., 2024; Ruban, 2024). Secondary indicators, such as human resources, industrial coordination, urban-rural relations, resource preservation, international trade, consumption level, and development scale, are used in the construction of indicators (Ding et al., 2022; J. Wang et al., 2022). This index technique has the advantage of being easy to calculate and can be expanded with various indicators, facilitating the future planning of the digital economy and making it easy to assess the development status of various dimensions (Li et al., 2022; Yi et al., 2022). However, the accuracy and scientific validity of this technique are often in doubt because the assignment, weighing and selection of indicators may be affected by subjectivity, and the results lack absolute significance (J. Wang et al., 2022).

This research examines the benefits and drawbacks of commonly used metrics in measuring digital economy growth at national and global scales. In addition, it explores the scientific validity of using Data Envelopment Analysis (DEA) to measure the level of digital economic development in cities and offers methodological insights for related studies.Data Envelopment Analysis (DEA) proved to be an effective tool in assessing the effectiveness of urban digital economic development and provided useful guidance for further improvement and development.

THEORETICAL REVIEW

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METHODOLOGY
Overview of the Data Envelopment Analysis (DEA) Method

One of the assessment methodologies often used in efficiency evaluation is Data Envelopment Analysis (DEA). DEA is a popular assessment technique that combines several academic fields, including operations research, economics, econometrics and statistics. The basic idea is to obtain relative efficiency indicators for each decision unit by thoroughly analysing the input and output data of the Decision Making Units (DMUs) (Hu & Zhao, 2024). Relatively effective DMUs are identified through ranking all DMU efficiency metrics (Lyu et al., 2023; Zhang et al., 2022). The main advantage of this method is its suitability for comprehensive assessment of the effectiveness of various inputs and outputs. The projection technique can also be used by DEA to determine the causes of weakness or ineffectiveness as well as the scope and direction of improvements required. This technique is commonly used in various study domains as a tool to provide information to managers in making management decisions (Lutfi et al., 2022). DEA is able to provide comprehensive information that supports management decision-making.

This research lies in the following important aspects:
1. Use of Data Envelopment Analysis (DEA) for the Urban Digital Economy
   This research offers a new approach in measuring the level of digital economy development in cities by using Data Envelopment Analysis (DEA). DEA allows for a more flexible and objective assessment of efficiency as it can allocate input and output weights endogenously, reducing the influence of subjectivity in the determination of weights. This approach differs from traditional scaling methods based on Gross Domestic Product (GDP) and index methods which are often affected by subjectivity in the selection and weighting of indicators.
1. Comprehensive Evaluation of Digital Economy Measurement Methods
   This research not only evaluates one measurement method, but also compares various techniques used in measuring digital economic growth, including the scale measurement method and the index method. This evaluation provides a more complete picture of the strengths and weaknesses of each method, and provides a basis for developing better methodologies.
2. A Multi-Dimensional Approach to Efficiency Assessment
   By combining several academic fields such as operations research, economics, econometrics, and statistics, DEA is able to handle the complex interactions between different aspects of the urban digital economy. This provides stronger support for smarter and more efficient managerial decision-making and digital economy development planning.
3. Practical Application to the Indonesian Urban Context
   This research also emphasises the importance of adapting the DEA model to the local Indonesian context, taking into account the unique factors that influence digital economy development in urban Indonesia. This provides a practical contribution to the development of more appropriate and effective digital economy policies and strategies.

With these innovations, this research not only enriches the literature on digital economy measurement, but also offers new tools and insights that can be applied in developing the urban digital economy more effectively and efficiently.

Benefits of Data Envelopment Analysis (DEA)

The advantage of the data envelopment analysis method is its high flexibility as it does not process data directly, which means that the best indicators for decision-making units do not depend on the selection of the dimensions of input and output indicator values.In addition, by using optimisation techniques, the data envelopment analysis method endogenously assigns input and output weights to decision-making units, thereby eliminating the influence of subjectivity in weight determination.Since fewer people are involved in the process, the results are more unbiased and convincing.Data envelopment analysis can be used to find areas that need improvement, assess effectiveness, and the current level of development of the system, which provides excellent support for decision-making.

The Concept of Using Data Envelopment Analysis (DEA) to Measure the Level of Development of the Urban Digital Economy

In more detail, cities can be considered as decision-making units, and the basis of the valuation model consists of inputs related to the digital economy (such as development of urban digital infrastructure, investment in human resources, etc.) and outputs (such as production from the digital economy).Successful cities in digital economy growth can be identified using Data Envelopment Analysis (DEA) models.The DEA model can handle this concern perfectly because the influence of urban digital economy involves several complex dimensions, including economic, political, social, and cultural environments (Aly, 2022). As shown earlier, data envelopment analysis is able to assess the effectiveness of urban digital economy development, identify cities that are more successful in this regard, and measure the level of development based on its effectiveness. More importantly, Data Envelopment Analysis (DEA) can provide guidance for city development and improvement by comparing digital economy development in other cities and identifying inefficient relationships or input elements (Cacciolatti, 2024). This is important for formulating plans that focus on digital economy development and for integrating the digital economy with overall city development (Liu, Zheng, et al., 2024; L. Wang et al., 2024).

RESULT AND DISCUSSION

This study aims to evaluate the techniques used to measure digital economic growth in urban Indonesia and investigate the validity of using Data Envelopment Analysis (DEA) for this purpose. The following are the main findings of this research:

Differences in Measurement Techniques

a. Scale measurement techniques that use Gross Domestic Product (GDP) principles and input-output methods show that there is significant variation in how different organizations measure digitalization and the contribution of the digital economy.

b. Index methods that use a number of indicators related to the digital economy show a lack of scientific validity due to subjectivity in the weighting and selection of indicators.

Weaknesses of Traditional Measurement Techniques

a. Scale measurement often has difficulties in comparison and evaluation due to differences in product classification rules as well as data limitations for new types of digital economy.

b. Index measurement has the advantage of ease of calculation and expansion of indicators, but its accuracy is questionable due to subjectivity in weighting.

Application of DEA

a. DEA offers great flexibility and can assign input and output weights endogenously, eliminating the influence of subjectivity in weight allocation.

b. DEA can identify cities that are rapidly growing in the digital economy and assess the effectiveness and development level of the current system.

c. DEA models are able to address the complex interactions between different aspects of a city, providing excellent support for managerial decision-making.

Analysis of the Advantages and Disadvantages of Measurement Techniques

a. Scale Measurement: Scale measurement using GDP principles and input-output methods is useful in determining the contribution of the digital economy to GDP. However, the main difficulty lies in comparisons between regions due to different classification rules and incomplete data for the new digital economy. For example, Tencent Information and Communication Technology Academy and BAE of the United States have implemented this approach, but face similar challenges.

b. Index Measurement: Index measurement with various indicators makes it easier to evaluate the dimensions of the digital economy. However, this technique is often affected by subjectivity in the selection of indicators and their weighting. Previous research shows that while this method is easily scalable, the validity and accuracy of the results are often questionable.

Benefits of DEA in the Context of Digital Economy Measurement

a. Flexibility and Weighting: DEA exhibits high flexibility in efficiency assessment by endogenously assigning input and output weights. This ensures that the influence of subjectivity in weight allocation is minimized. For example, in a study applied to major European cities, DEA successfully identified cities with rapid growth of the digital economy and reduced the impact of complex interactions between different aspects of the city.

b. Support for Decision Making: DEA analysis can be used to find areas that require improvement, assess effectiveness, and the current level of system development. It provides strong support for managerial decision-making, especially in planning for a smarter and more efficient future of the city.

c. Application in City Development: DEA measurements can be integrated with the coordinated long-term development of cities, providing a new perspective on how to measure the effectiveness of economic development in related studies. This is important for formulating more targeted and effective digital economic development plans.

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DISCUSSION

This study examines several methods of measuring the digital economy, namely the Gross Domestic Product (GDP)-based scale measurement method and the input-output method, as well as the index method. Scale measurement methods using the GDP principle and the input-output method show significant variations in the measurement of digitalisation and the contribution of the digital economy. The advantage of these methods is their ability to directly reflect the level and scope of development of the digital economy and calculate its contribution to GDP. However, it faces challenges in inter-regional comparisons due to differences in product classification rules and data availability for new types of digital economy. The index method involves selecting a number of indicators related to the digital economy, building a comprehensive indicator system, and using quantitative indicators to show the level of development of the digital economy. This method facilitates the calculation and development of indicators, facilitates the future planning of the digital economy, and enables the assessment of the development status of various dimensions. However, the accuracy and scientific validity of this technique are often doubted due to the subjectivity in weighting and selecting indicators.

CONCLUSIONS AND RECOMMENDATIONS

To conclude, scale measurement and index measurement are the two main categories on which digital economy measurement techniques are based, both at home and abroad. Although both approaches have their own advantages and disadvantages, they are not reliable enough to measure the extent of urban digital economy development. Therefore, this study suggests a new approach to measure the level of development of urban digital economies: Data Envelopment Analysis (DEA).

For example, the DEA model has been successfully applied in major European cities to measure the efficiency and development of the digital economy. Using DEA models, cities that are thriving in the digital economy can be identified, while helping to reduce the impact of the complex interactions between different aspects of the city. More importantly, the DEA model's measurement of the level of digital economy development can be integrated with the city's coordinated long-term development. This provides a new perspective on how to measure the effectiveness of economic development in related studies, and helps policy makers to make better decisions in planning for a smarter and more efficient urban future.

For future research, some recommendations that can be given are as follows:

1. Data Development and Product Classification: Conduct further research to develop more comprehensive and consistent data related to the digital economy, as well as harmonise domestic and international product classification rules to facilitate comparison between regions.
2. Index Method Improvement: Reduce subjectivity in weighting and indicator selection in index methods by developing a more objective and data-driven approach. The use of more sophisticated analytical techniques can help in improving the accuracy and validity of measurement results.
3. Adaptation of DEA to Local Context: Conduct additional research to adapt the DEA model to the local Indonesian context. This includes considering the unique factors that influence digital economy development in urban Indonesia, such as digital infrastructure, human capital investment, and government policies.
4. Longitudinal Research: Conduct longitudinal studies to monitor the development of the digital economy over time. This will provide deeper insights into the dynamics of change and the factors contributing to the growth of the digital economy in different cities.
5. Collaboration between Researchers and Institutions: Encourage collaboration between researchers, academic institutions, government and industry to collect richer data and share best practices in measuring and developing the digital economy.

With these recommendations, it is hoped that future research can overcome existing limitations and make a more significant contribution to the measurement and development of the urban digital economy.

FURTHER STUDY

This study has several limitations that need to be considered. First, the use of scale and index measurement methods faces challenges in terms of inter-regional comparisons due to differences in domestic and international product classification rules and limited data for new types of digital economy. These limitations may affect the accuracy and validity of the research results. Secondly, subjectivity in determining weights and selecting indicators in the index method is also a major obstacle that can reduce the reliability of digital economy measurement results. In addition, the adaptation of the Data Envelopment Analysis (DEA) model to the local Indonesian context requires further research to ensure that the unique factors affecting digital economy development in urban Indonesia are properly accommodated.

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