# Navigating the Paradox of Digitalization: A Multidimensional Analysis of the Digital Economy in the Greater Bay Area

Yumeng Zhang [1], Wenjing Cui [2, *], Nan Yao[3]

zhangyumeng@gdust.edu.cn[1], cuiwenjing@gdust.edu.cn[2], yaonan@gdust.edu.cn[3]

Guangdong university of science & technology, Dongguan, China

**Abstract.** This study delves into the pattern of digital economy development in the Guangdong, Hong Kong and Macao Greater Bay Area, and provides detailed forecasts of the development trend of the digital economy index of each prefecture-level city in the next three years. Drawing on authoritative government statistics, this study adopts a multidimensional analytical framework that combines economic indicators and digital economy indexes. Under a robust theoretical framework, this study applies stepwise regression analysis and ARIMA forecasting, and finds that GDP per capita and the tertiary industry have a significant positive impact on economic growth, while the digital economy index exhibits an unexpected negative impact. The innovation lies in combining the prediction model with regional stratification, revealing differences that require strategic policy interventions to achieve balanced development of the digital economy. Future research directions aim to address emerging socio-economic and policy challenges in the digital era.

**Keywords:** Digital economy; Added Value of Tertiary Industry; Guangdong-Hong Kong-Macao Greater Bay Area (GBA); ARIMA model.

## 1. Introduction

The Guangdong-Hong Kong-Macao Greater Bay Area (GBA) is a complete and vibrant economic centre of gravity in China, situated at the heart of a dynamic and stable economic backdrop. It is part of the GBA, which includes Hong Kong and Macau Special Administrative Regions as well as nine cities from Guangdong Province in mainland China. One of the world's most influential city clusters, it comprises more than 60 million people. The GBA has revealed high growth in development and innovation for the digital economy and artificial intelligence in the past years becoming a critical agent of transitions in regional economic transformation and upgrading industries [1]. The GBA, with "one country, two systems", "three customs zones" and "three currencies", it is one of the most economically developed and dynamic regions in China. It is strategically important in the overall development of the country. However, significant gaps remain, particularly in the tertiary sector and GDP per capita. Considering the representativeness, relevance and importance of the GBA, this paper selects nine mainland cities (Guangzhou, Shenzhen, Zhuhai, Foshan, Dongguan, Huizhou, Zhongshan, Jiangmen, Zhaoqing) in the GBA as the study area.

IEDM 2024, February 23-25, Kuala Lumpur, Malaysia

DOI 10.4108/eai.23-2-2024.2345929

The digital economy, which is a characteristic feature of the economic modernization that occurred at the new era stages has penetrated into various sections and industries across the Greater Bay region. The regional economic model is changing with the support of information technology advancements, digital infrastructure establishment, implementation of digital technologies and innovations in digital services. This transformation leads to betterment in the process of economic efficiency, improved industrial structures and upgrade quality life for citizens.

The significance of this study lies in the in-depth analysis of the current development of the digital economy in the GBA, and the construction of a comprehensive theoretical framework through the assessment of the regional economic and social impacts based on four key dimensions: total GDP, GDP per capita, Added Value of Tertiary Industry, and the Digital economy index. In order to fully examine the evolution of the digital economy, the study incorporates perspectives from the fields of economics, technology, society, and policy. Fine-grained regional analyses and industry insights are provided, offering new perspectives on the role of the GBA in the current technological revolution and industrial transformation.

## 2. Literature review

### 2.1 Development of the digital economy

Particular emphasis has been placed on the digital economy phenomenon, which is thought to be a key driver of economic growth in the twenty-first century. Information and communication technology has been responsible for much of the digitization that has replaced physical work [2]. With the emergence of the Internet, data developments and performance which include internet awareness information technologies has accelerated innovation together with realized growth deserving chapter to help rule online economy. The effects of digital economy are not no more than evolution but revolution; it redefines historical economic patterns while creating new ones – the sharing or platform economics [3]. We can notice that there is a process of disruption in the digital economy, not only in the sense that it disrupts old business models per se, but also in the transformation that ensues. In the context of regional development, diverging tendencies are visible in terms of technological advancement led by the digital economy through different countries. The studies have demonstrated that digital economy is simply complex and this is caused by many factors. In bringing out the unification of these studies, it clearly underpins the necessity for formulating area-specific innovations to regulate the nuances that surround digital economic life.

### 2.2 Guangdong, Hong Kong and Macao GBA Related Research Literature

Scholars are paying more and more attention to the GBA, which is a major force behind China's economic growth, particularly when considering the digital economy. Chen et al. performed an analysis of the present-day situation and prospects for the modernization of digital economy in GBA, emphasizing regional integration, industrial harmonization and innovative approaches as important factors assisting [4]. Dang et al. used principal component analysis to create three indices to measure the economic development of the GBA over the period 2010-2019, and found that the GBA had a very rapid integration process [5]. However, Yang discovers that between 2008 and 2019 there was a regional variation in the relatively

low level of economic synergistic development of the city clusters in the GBA [6]. Geographic distance has a negative impact on the GBA Digital Technology Innovation Alliance, although institutional and technological proximity has a beneficial impact, according to Chen [7]. Though perusal of Google Scholar and China Knowledge Network as related articles which analyze GBA digital economy current stats and contains historical data is conducted, this paper makes more contribution by looking at the future with a research gap and improves the audience understanding of the complex dynamics of the digital economy in the GBA for better future research.

## 3. Research methodology

### 3.1 Research framework

This study aims to develop a unified theoretical framework that will assist in the analysis of the growth dynamics concerning Data Economy specific to the GBA. This framework encompasses four pivotal dimensions: total GDP, GDP per capita, Added Value of Tertiary Industry, and the Digital economy index. To understand where the development of the digital economy is heading, Schumpeter's innovation theory has become a basic reference that proposes technology innovation as an essential driving force for overall economic growth [8]. Next, we base our stand on Porter's competitive advantage theory as an additional proof to demonstrate that the concern of industry structure transformation and upgrading contributes managing for the development of techonomic [9]. For the purpose of this work, we are planning to apply these theories in a way they would give the most holistic description about how the digital economy would enclose social and economic structures.

In conclusion, the research approach we propose is comprehensive. This powerful framework can help this study to explain the development of the digital economy in the GBA and its future predictions.

### 3.2 Data sources

The secondary data for this study are comprised of official statistics. First of all, official statistics derived from authoritative government institutions such as the National Bureau of Statistics and GBA Development Bureau becomes the basis for analysis. These data, known for their authoritativeness and trustworthiness [10], can form a solid basis of the analysis model. Then, these white papers provide in-depth analyses and future outlooks of the industry. In addition, going through the literature review it has been revealed that research outcomes from previous studies provide a theoretical foundation and are critical to reference this study [11, 12].

### 3.3 Modelling

The theoretical framework used in this study integrates a number of implicit and explicit models to advance the analysis of the digital economy. Based on this, a comprehensive theoretical framework was developed as shown in **Figure 1**. The framework mainly consists of the four economic indicators analysed in this study (GDP, GDP per capita, Added Value of Tertiary Industry and the digital economy index), through authoritative government statistics, stepwise regression analysis and ARIMA forecast analysis were carried out. Within this robust

theoretical framework, its impact on economic development is explored, while the link between these dimensions and their cumulative effect on the evolution of the digital economy is demonstrated.

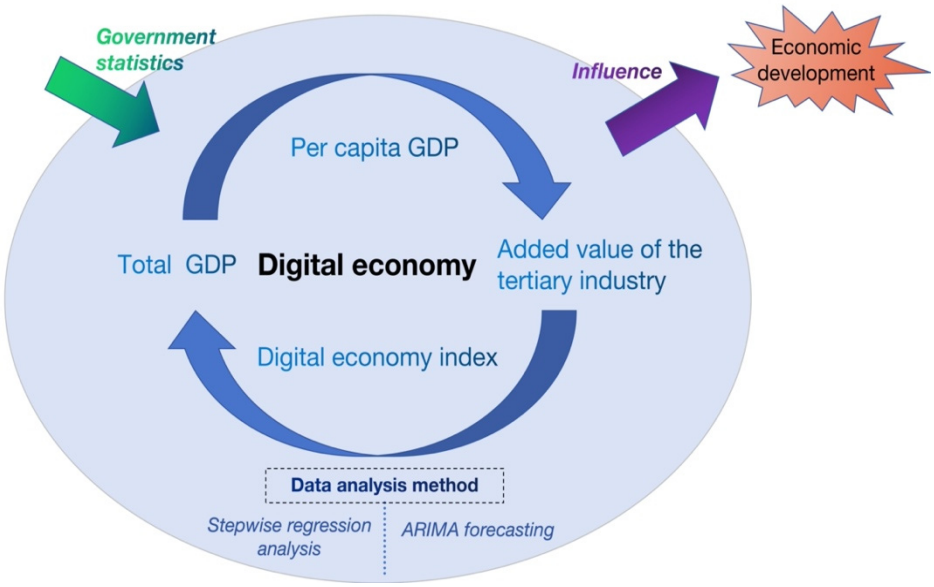


**Fig.1.** Research model diagram

## 4. Data analysis

In this study, the data analysis will be primarily centered on nine mainland cities. This targeted analysis guarantees deep understanding about the specific features of the GBA helping to provide adequate wisdom for economic openness vs. digital economy relationship and region progression.

### 4.1 Basic data analysis

The digital economy in 2019 has reached over USD 4 trillion, accounting for 44% of the GDP of the Bay Area. In 2022, the total GDP of the nine cities in the GBA is up to RMB 10.46 trillion yuan. The information technology sector came to dominate the digital economy, essentially featuring the Internet, big data and cloud computing. The GBA Digital Economy Development Report 2023 states that Guangdong province's digital economy contributed 6.4 trillion yuan to GDP, or 12.8% of the added value of the country's digital economy. This made Guangdong province the top contributor for the sixth year in a row [13].

This underscores the GBA's role as China's most dynamic digital economy hub. Specifically, Guangdong's digital economy constitutes 49.7% of the regional GDP, serving as a pivotal engine for the region's high-quality economic development. The integration of emerging information technology industries, such as artificial intelligence, industrial internet, and cloud computing, has propelled digital industrialization. Meanwhile, the pearl river delta’s

traditional manufacturing industry is still enormous and transformation and upgrade are inevitable development steps which would open up a wide range market for industrial digitalization.

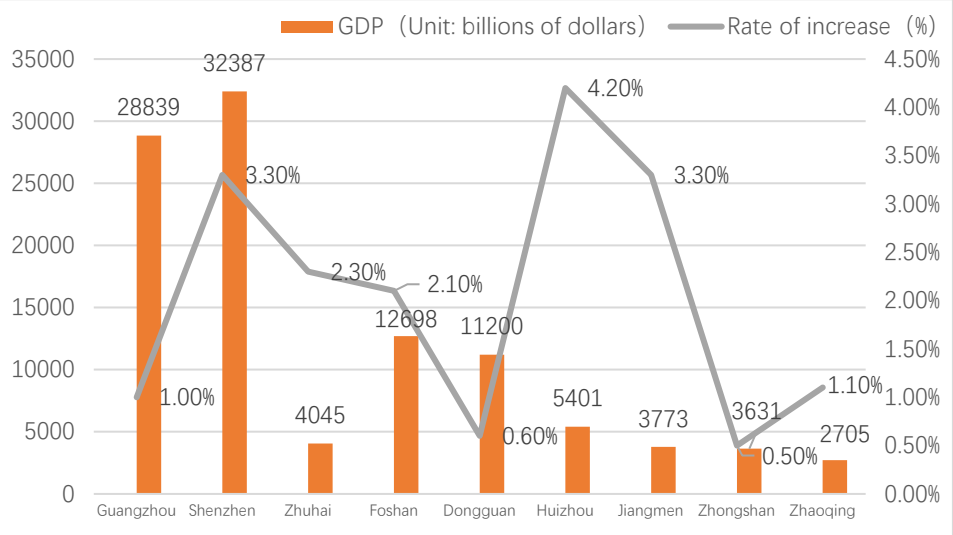


**Fig.2.** Regional GDP and growth rates of nine mainland cities in the GBA in 2022

Nevertheless, there are still many obstacles that need to be overcome. Discrepancies in the levels of economic development and the stages of digital economy development between cities are still noticeable. **Figure 2** exhibits the GDP and growth rates of the nine cities in last year. It is noteworthy that Shenzhen, Dongguan, Foshan, and Guangzhou have higher GDP contributions from the digital economy than the national average. This difference can be attributed to a variety of factors, including but not limited to differences in the degree of industrial digitisation and innovation capacity. Through in-depth analysis, the complex relationship between digital economy and regional economy is found. While the digital economy has driven regional GDP growth to some extent, the uneven distribution also highlights the digital divide within the region. This phenomenon requires us to reassess the relationship between digitalization and economic prosperity, challenging the conventional view that technological progress inevitably leads to economic prosperity. The picture is the snapshot of the current economic development focus of the region, and at the same time is a bell for intervention of policies. The policymakers can make an effective use of the full potential of the digital economy to achieve the regional economic integration and also to ensure equitable distribution of economic development benefits. The paper stresses the need of adopting a holistic and all-inclusive strategy for the economic development which serves as a foundation to realize the panorama of the GBA as a guarantor of a harmonious and self-sufficient development.

### 4.2 Stepwise Regression Analysis

In this section, conducting stepwise regression analysis (stepwise method) with the GDP per capita, Added Value of Tertiary Industry, and Digital economy index over a span of seven

years across nine cities as the independent variables, and the total GDP as the dependent variable. Following model automation, the resultant model retained three variables: GDP per capita, Added Value of Tertiary Industry, and Digital economy index. The R-squared value of 0.977 indicates that the Added Value of Tertiary Industry, Digital economy index explains 97.7% of the variation in GDP total. Besides, the model got the F-value ($F=818.368$, $p=0.000<0.05$), meaning that it was effective. The model equation is represented as follows: GDP total = 5502.471 + 0.012 * GDP per capita + 1.628 * Added Value of Tertiary Industry - 12415.491 * Digital Economy Index. The elaborated data is given in **Table 1.**

The results of analysis reveal that the bout for GDP per capita is 0.012 ($t=2.029$, $p=0.047<0.05$), which denotes a positive significant relationship with GDP total. This reflects the prevailing economic perception that an affluent population with higher disposable incomes contributes more to the economic output of cities. Added Value of Tertiary Industry equal to 1.628 ($t = 14.136$, $p <0.0001$), indicates that Added Value of Tertiary Industry and GDP are significantly and positively associated. indirectly suggesting that cities with a higher proportion of service and tertiary activities tend to have higher GDP. This is consistent with the global economic trend that a shift to a service-based economy tends to be associated with higher levels of economic development and prosperity.

However, a negative relationship (-12415.491) is illustrated by digital economy index coefficient ($t=-2.455$, $p=0.017<0.05$), which is an interesting finding. This suggests that an increase in the Digital Economy Index may represent a higher level of digitisation and technological integration in the city's economy, but is associated with a decrease in total GDP. This counter-intuitive result may suggest that although digital economy initiatives are being developed and implemented, they may not yet be contributing fully to economic output as expected, or they may be displacing traditional sectors without being adequately compensated in terms of GDP contribution. This can be a sign of a transitional stage where digitalization hasn't matured enough to benefit the economy as a whole, or it may indicate that inefficiencies and challenges within the digital sector are holding back economic growth.

In summary, **Table 1** provides important insights into the economic dynamics of the GBA, highlighting the positive impact of GDP per capita and tertiary activities on the city's economic output. However, the negative correlation between the digital economy index and total GDP deserves further investigation. Policymakers should take this analysis into account when designing and implementing digital economy strategies.

**Table 1.** Results of stepwise regression analysis

| Stepwise regression analysis results (n=63) | | | | | |
|---|---|---|---|---|---|
| | Unstandardised coefficient | Standardised coefficient | | | |
| | *B* | Standard error | Beta | *t* | *p* |
| constant | 5502.47 | 2075.69 | - | 2.651 | 0.010* |
| GDP per capita | 0.012 | 0.006 | 0.057 | 2.029 | 0.047* |
| Added Value of Tertiary Industry | 1.628 | 0.115 | 1.124 | 14.136 | 0.000** |
| Digital Economy Index | -12415.491 | 5057.94 | -0.184 | -2.455 | 0.017* |
| $R^2$ | | 0.977 | | | |
| Adjusted $R^2$ | | 0.975 | | | |

| | |
|---|---|
| F | F(3,59)=818.368, *P*=0.000 |
| D-W value | 0.606 |

Dependent variable: GDP total; * $p<0.05$ ** $p<0.01$

### 4.3 Comparative analysis of seven-year averages and forecasts

First, for 9 mainland cities, the average value of the 7-year digital economy index from 2016 to 2022 was calculated. Then ArcGIS software was used for editing combined with geographic information, and natural segmented point classification method was adopted, as shown in **Figure 4.** Then, the forecast analysis from 2023 to 2025 was carried out using the ARIMA model, which consists of three main parameters, namely: the autoregressive order (p) which aims at capturing the series effect of the past values of the time series itself; the difference order (d) that shows the number of differences required to obtain a smooth and uniform time series; the moving average term order (q) which represents the number of lags in the prediction error. ADF test and partial (auto-) correlation analysis were performed on data, and, after several recasts of testing, final results of **Table 2** were obtained.

**Table 2.** Data presentation of optimal model parameters (p,d,q)

| | autoregressive order（p） | difference order (d) | moving average order (q) |
|---|---|---|---|
| Huizhou | 0 | 1 | 0 |
| Guangzhou | 0 | 1 | 0 |
| Shenzhen | 1 | 2 | 1 |
| Zhuhai | 0 | 0 | 0 |
| Foshan | 0 | 2 | 0 |
| Dongguan | 0 | 1 | 0 |
| Zhongshan | 0 | 1 | 0 |
| Jiangmen | 0 | 1 | 0 |
| Zhaoqing | 0 | 1 | 0 |

The ARIMA model is used to predict the future trends of the digital Economy Index for each city in 2023-2025, as the **Figure 3** depicts. The dotted line shows the digital economy index development of nine mainland cities in the GBA from 2016 to 2022, while the solid line shows the expected level of these indicators from 2023 to 2025. Forecasts from 2023 to 2025 reveal stark contrasts in digital economy growth across cities in the GBA. Guangzhou, Shenzhen and Foshan have continued to achieve strong growth thanks to their advanced digital infrastructure, favourable policy environment, rich talent pool and strong industry specialisation. These cities have become centres of innovation and digital entrepreneurship, driving their digital economies at an impressive pace. On the other hand, the remaining cities have shown a more moderate growth trajectory, with some of them approaching a plateau. This disparity may stem from limited investment in digital infrastructure, poor regulatory conditions, a narrow talent base, and a lack of industry diversity. These factors have led to a slowdown in digital integration and innovation, preventing these cities from keeping pace with fast-growing cities. The divergent trends highlight the need for targeted policy interventions and investments to bridge the digital divide and ensure that all cities in the region are able to fully harness the benefits of the digital economy and achieve sustainable and inclusive growth. Meanwhile, the ArcGIS software was used to edit the geographic information of the future projections, as shown in **Figure 5.**

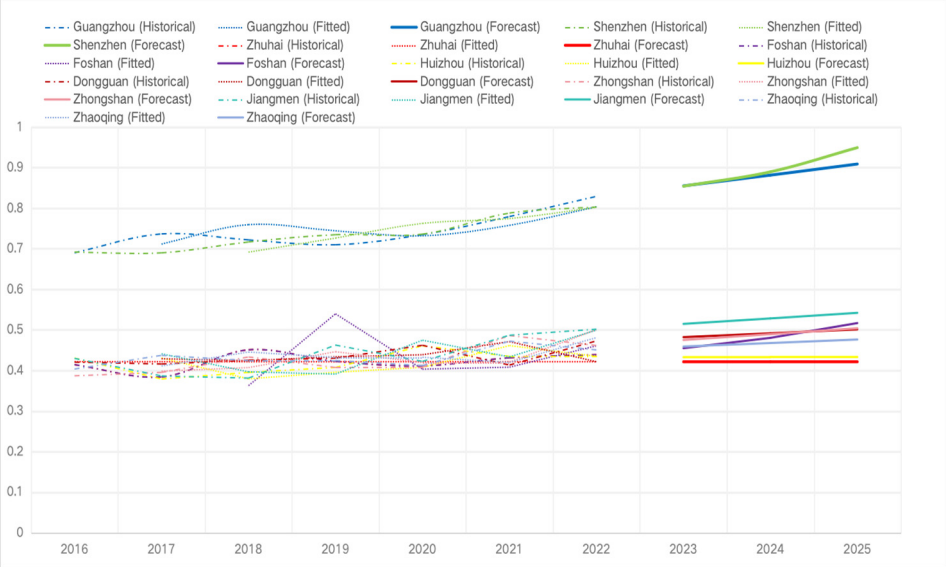


**Fig.3.** Urban Data and Forecast (2023-2025) Using ARIMA Model

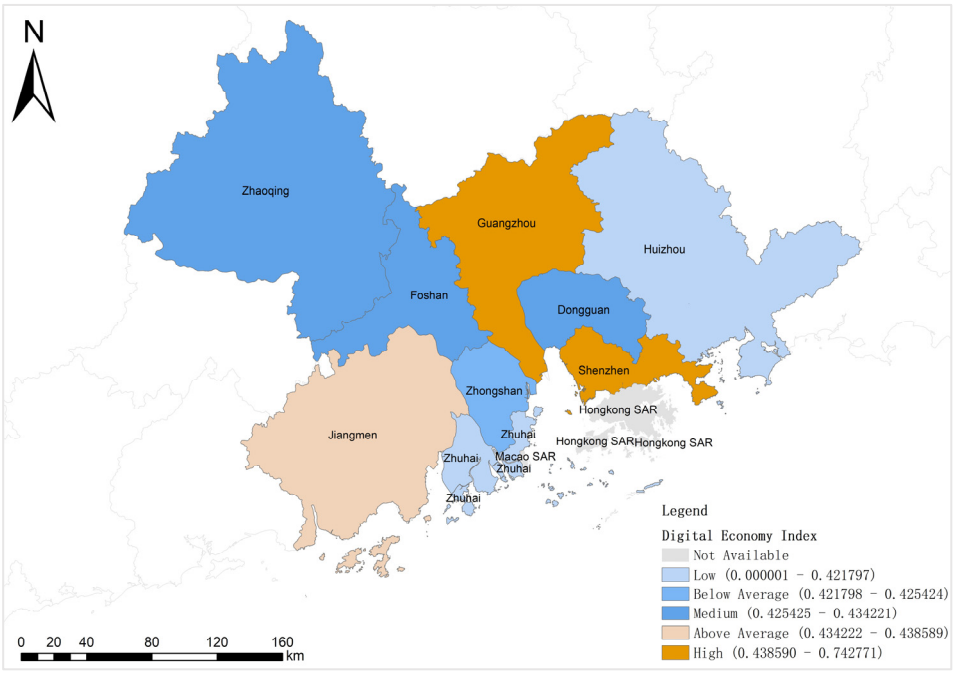


**Fig.4.** Average geographic information of the 7-year digital Economy Index for each city

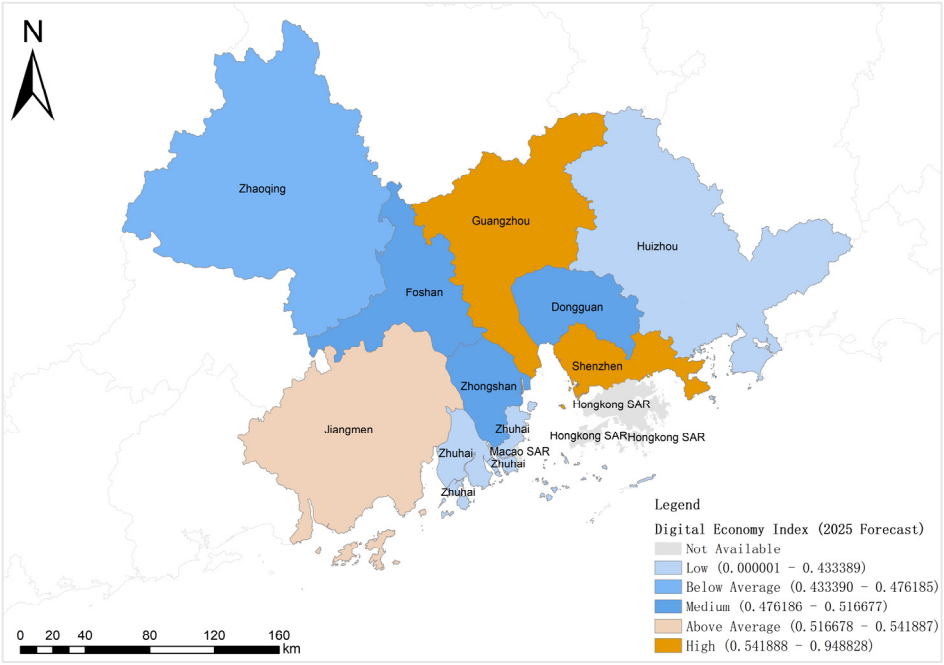


**Fig.5.** Each city's future forecast digital economy index geographic information

The comparative analysis of the two maps above reveals a clear spatial trend in the development of the digital economy in the GBA. **Figure 4** represents the average geographic information of the seven-year Digital Economy Index from 2016 to 2022, showing the centralised development of core cities such as Shenzhen and Guangzhou, with clear boundaries compared to peripheral cities. This difference highlights the existing digital divide, with core cities taking advantage of their advanced infrastructures, policy environments, and innovation ecosystems to achieve a significant lead in digital economy development. On the other hand, **Figure 5** predicts the future trend of the Digital Economy Index from 2023 to 2025 based on the projections of the ARIMA model. Guangzhou, Shenzhen and Foshan were found to continue their strong growth trends and are expected to maintain or even strengthen their digital economy growth trajectories. In contrast, the other cities are growing at a slower pace. This difference can be attributed to the varying degrees of digital infrastructure, government support, and innovation capabilities across cities.

These two side-by-side maps highlight not only the progress made, but also the persistent gap between digital economy leaders and laggards in the GBA. The sustained capacity of the core cities illustrates past and current successful strategies in terms of digital infrastructure investment, innovation ecosystem nurturing and policy support. Meanwhile, stagnant or slow growth in other cities reminds us of the need for targeted interventions to enhance digital capabilities and integration in these lagging areas.

## 5. Conclusions

The study kicked off a systematic observation of the digital economy in the wider area of Guangdong-Hong Kong-Macao Greater Bay Area (GBA). By means of our in-depth data that covers per capita GDP, Added Value of Tertiary Industry and other variables, we finally present you with the compelling findings of what really drives the GBA's dynamic economy. The results reveal a complex relationship, and while Guangzhou, Shenzhen and Foshan, among others, continue to show strong growth in the future, fuelled by digital innovation, economic output in other regions has stagnated or grown only marginally, suggesting a subtle digital divide. Meanwhile, by chance an unexpected thing emerged from the analysis of the findings: it seems that the index of the digital economy in some cases is against the growth of total GDP. With the digital economy managing to do just the opposite from what it was intended for, our perception of digital growth acquires an entirely new meaning, unfolding a paradox within the digital economy itself.

The negative coefficient associated with the digital economy index exposes underlying tensions in the digital growth narrative. It prompts a critical re-evaluation of the assumption that digitalization unilaterally translates to economic prosperity. In many respects it challenges a basic viewpoint that in regard to a digital economy, the higher the technological advancement, the higher the economic prosperity. But our data seem to indicate that after a critical delimit, the increase of the digital economy index doesn't push economic growth further and instead introduces inefficiencies via market monopolization, decreased competitiveness while leading to wider digital divide. This presents scholars studying digital economy metrics with a conundrum of unraveling complexities and their implications to real-life economies. The study's outcomes highlight the imperative for policy frameworks to mitigate the adverse effects identified.

The data analysis process produces several aspects that are considered essential. The first aspect of the society’s response to speed of digitalization must consider the workforce displacement, as well as the privacy problems. Such approach should be balanced between technological developments and social issues. Therefore, the policy field is expected to transform to cope with these difficulties before they become dealbreakers. Not only government policies should introduce innovative practices but they must assemble facilities and infrastructure in order to create a digital environment which will be inclusive for all. More significantly, a cautious digital institution is needed to ensure that everyone has access to the opportunities presented by the digital economy and to connect citizens to the digital gap. The regulatory stance should furthermore be moulded to function seamlessly in a digital environment that is fast-paced by the protection of personal data and security and creation of competitive markets.

In conclusion, our outcomes stress on the area of digital economy impact on the GBA. In the same way, the digital economy shines the light of economic opportunities, however there are also threats that may thwart this progress. These dual aspects are emphasized by the research, so we have a highly sophisticated view on what digital economy brings to the regions, thus contributing to the academic discussion and policy arrangements. In the future, research should strive to unravel these not so obvious complexities, particularly by in-depth investigation of long-term social and economic consequences of digitation. Practical and

theoretical knowledges will help us identify the appropriate chances and threats of the rapidly changing age of technology and make positive judgements related to the future of the GBA.

**Acknowledgment.** The authors wish to express their sincere gratitude to all those who provided invaluable assistance throughout the course of this study. Our thanks are extended to the colleagues and reviewers who contributed their expertise and offered constructive criticism that greatly improved the manuscript. Special acknowledgment must go to the team members whose persistent efforts and collaborative spirit were the linchpins of this research project. We would also like to acknowledge the financial support from the Guangdong University of Science & Technology, without which this research would not have been possible. This grant has not only provided the means but also the encouragement to pursue and refine the inquiries that laid the foundation of this work. Lastly, our heartfelt thanks to our families for their unwavering support and patience during this demanding academic pursuit.

**Funding.** Doctoral Research Start-up Fund of Guangdong University of Science & Technology [grant number: GKY-2023BSQD-27]

## References

[1] Wu, A. Y., Wut, T.-m., Lau, Y.-y.: Current Context of Urban Development in China: Collaborative Innovation for Smart Cities. In SDGs in the Asia and Pacific Region: Springer. pp. 1-23 (2023).

[2] Bukht, R., Heeks, R.: Defining, conceptualising and measuring the digital economy. Development Informatics working paper. no. 68 (2017).

[3] Richter, C., Kraus, S., Brem, A., Durst, S., Giselbrecht, C.: Digital entrepreneurship: Innovative business models for the sharing economy. Creativity and Innovation Management. vol. 26, no. 3, pp. 300-310 (2017).

[4] Chen, D., Xiao, Y., Huang, K., Li, X.: Research on the Correlation and Influencing Factors of Digital Technology Innovation in the Guangdong–Hong Kong–Macao Greater Bay Area. Sustainability. vol. 14, no. 22, p. 14864 (2022).

[5] Dang, V. Q., Kwan, F., Lam, A. I.: Guangdong–Hong Kong–Macao Greater Bay Area (GBA): Economic progress, diversification, and convergence. Journal of the Asia Pacific Economy. pp. 1-31 (2023).

[6] Yang, J.: Economic synergistic development of Guangdong-Hong Kong-Macao greater bay area urban agglomeration: Based on composite system. Computational Intelligence and Neuroscience. (2022).

[7] Chen, D., Xiao, Y., Huang, K., Li, X.: Research on the Correlation and Influencing Factors of Digital Technology Innovation in the Guangdong–Hong Kong–Macao Greater Bay Area. Sustainability. vol. 14, no. 22, p. 14864 (2022).

[8] Schumpeter, J.: The theory of economic development: An inquiry into profits, capital, credits, interest, and the business cycle. Harvard University Press, Cambridge, MA (1934).

[9] Porter, M. E.: The competitive advantage of nations. Harvard Business Review. vol. 73, p. 91 (1990).

[10] Ubaldi, B.: Open government data: Towards empirical analysis of open government data initiatives (2013).

[11] Choy, L. T.: The strengths and weaknesses of research methodology: Comparison and complimentary between qualitative and quantitative approaches. IOSR Journal of Humanities and

Social Science. vol. 19, no. 4, pp. 99-104 (2014).
[12] Vasileiou, K., Barnett, J., Thorpe, S., Young, T.: Characterising and justifying sample size sufficiency in interview-based studies: Systematic analysis of qualitative health research over a 15-year period. BMC Medical Research Methodology. vol. 18, pp. 1-18 (2018).
[13] PwC: GBA Digital Economy Development Report 2023 (2023). [Online]. Available: https://www.pwccn.com/zh/research-and-insights/greater-bay-area/publications/gba-digital-economy-report-2023.html.