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Tax deduction or financial subsidy during crisis? Effectiveness of fiscal policies as pandemic mitigation and recovery measures

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A B S T R A C T

Economic analysis of the tourism industry is a critical tool for local industries and governments to estimate, understand, and forecast the tourism potential and economic performance of a destination, especially amidst a crisis such as the COVID-19 pandemic. In this study, we take Macao as a case study, perform an analysis using an input-output framework. By constructing a tourism satellite account and a dynamic stochastic general equilibrium model, we estimate the contribution of the tourism industry to the economy of Macao and assess the ramifications of several government policies to mitigate the impact of COVID-19. Our findings provide the Macao government and local industrial stakeholders with critical information for pandemic mitigation and recovery strategies.

1. Introduction

The COVID-19 pandemic had a protracted impact on the global economy. Many industries were overwhelmed by new and emerging challenges in logistics, staffing, and capital chain ruptures, among other issues, and they continue to cope with long-term effects. The tourism industry, in particular, faced severe challenges and suffered heavy losses. Destinations with a heavy reliance on tourism, such as Macao, experienced dramatic downturns in their inbound tourism markets. Going forward, it is crucial for destinations like Macao to explore effective ways to mitigate the impact of the pandemic and facilitate quick recovery.

Macao has a strong reliance on tourism industry. The rapid development of tourism and gaming industry in Macao since its return to China in 1999 has been the major force that powered its economic development. According to the Statistics and Census Service Department (DSEC), the GDP of Macao increased from MOP51.9 billion in 1999 to MOP434.7 billion in 2019, reflecting a threefold real growth across a 20-year span (DSEC, 2020a). Since 1999, per capita GDP has more than doubled and the unemployment rate has decreased by three times (DSEC, 2020a). The rapid expansion of the service industry is the primary reason for the remarkable development of the economy of Macao. Over the past decade, the share of GDP contributed by the service industry has gradually increased, reaching more than 95% in 2018. The tourism industry is one of the pillar industries of Macao. In recent years, tourism-related businesses (including gaming) have accounted for more than 60% of all economic activities in Macao (World Travel and Tourism Council, 2018). DSEC (2020b) reported that the total volume of inbound tourists reached 35.8 million in 2018, which is 110% of the 2017 volume and 480% of the 1999 volume. With a population of merely 0.67 million people, each Macanese resident hosts about 50 tourists on average each year.

The tourism industry's crucial role in Macao's economy translates into a heavy dependence on this sector. In 2018, the revenue from the gaming sector alone exceeded MOP303.9 billion, and other tourism-related businesses, such as retail, hospitality, and catering, earned MOP69.7 billion (DSEC, 2020b). Meanwhile, of the 0.38 million persons working in Macao, every second employee participates in a business related to tourism and hospitality. The high revenue derived from the tourism industry and the number of residents participating in the sector

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reflects the government's heavy reliance on tourism as well as a significant risk: small fluctuations in the tourism industry significantly impact Macao's entire economy. Therefore, knowledge of how the tourism sector influences and interacts with other industries is critical for developing economic recovery plans amidst the COVID-19 pandemic and for reacting to future crises.

Successful crisis management and recovery planning relies on the collection of accurate and timely data on the tourism industry and related sectors. In Macao, accurate information on tourists, both in terms of border statistics and consumer big data, forms the foundation of the policies adopted by tourism stakeholders, while precise information on destinations in Macao helps tourists make plans and decisions. In academia, several studies have described how information can assist and accelerate the development of tourism (Li, Xu, Tang, Wang, & Li, 2018; Mariani, Baggio, Fuchs, & Höepken, 2018). Macroeconomic information has proven to be particularly effective for analysing and forecasting tourism activities (Chaiboonsri & Wannapan, 2017; Song & Liu, 2017). Nevertheless, the government of Macao does not have a regular entry for the tourism industry, or for relevant sub-sectors of related industries, in the national accounting system. Due to the heterogeneity and plurality of tourism products, tourism lies at the intersection of several industries, making it difficult to directly trace its connections with other sectors (Candela & Figini, 2012). Therefore, the identification and measurement of tourism-related activities across Macao's economy is crucial for a macro-level analysis of the tourism industry.

The tourism satellite account (TSA) is widely accepted as one of the best tools for capturing the contribution of the tourism industry to the local economy (Frechtling, 2010). A TSA is constructed from an input-output (I-O) table of an economy, with a particular focus on tourism activities. By identifying and measuring the capital flows between the tourism industry and other parts of the economy, the TSA can help quantify the contribution of tourism consumption to the economy of a region. Beyond the I-O framework, general equilibrium models use real-world data to determine the relationships and interactions among different sectors of an economy. The dynamic stochastic general equilibrium (DSGE) model captures intertemporal dynamics and idiosyncratic shocks and provides simulated results that predict future economic trends under various scenarios. Despite the merits of the TSA and DSGE models, Macao has yet to develop a thorough analysis using these tools because the Statistics and Census Service of Macao has not yet constructed an I-O table. This can partially be attributed to the skewed economic structure in Macao and the extreme concentration of the gaming sector in Macao's economy. Through this study, we aim to fill this gap by constructing an I-O table for Macao and assessing recent developments in Macao's tourism industry and economy using the TSA and DSGE models.

After the severe economic impacts of the COVID-19 pandemic, the government of Macao sought to mitigate the immediate and long-term aftermath of the crisis. Specifically, the government implemented two major fiscal measures to stimulate the economy, namely tax reduction and consumption vouchers. In early 2020, the government waived the tourism tax, professional tax, and property tax (Deloitte, 2020) and injected multiple rounds of consumption vouchers into the economy (Lai, 2022). While some anecdotal evidence describes the effectiveness of these measures, such as over 7.2 million beneficiaries among the local population and around 0.7% direct contribution to local GDP growth (Magramo, 2021), no rigorous quantitative evidence exists to confirm the effectiveness of the policies. Therefore, alongside our construction of an I-O table for Macao, we also use the DSGE model to simulate the effectiveness of these policies in the long-run and provide relevant policy recommendations. Throughout the modelling process, we would like to accomplish the following objectives:

1. Construct an I-O table and a TSA for Macao;
2. Build a DSGE model based on the constructed I-O table and TSA;
3. Examine the impacts of various policies through simulations of the DSGE model; and
4. Assess the effectiveness of these various policies accordingly.

The rest of this paper is structured as follows: in the next section, we review relevant literature on Macao's tourism industry and analyses of the TSA and DSGE models. In the third section, we explain our procedure for and results of the TSA analysis. In the fourth section, we construct a DSGE model and examine simulation results for different crisis mitigation and economic recovery policies. In the last section, we discuss the ramifications of the results and our conclusions.

2. Background and literature review

2.1. The Macao tourism industry

Macao is often referred to as the 'Las Vegas of the East', as resorts and casinos have become the calling card of the city (Sheng & Gu, 2018). Due to the heavy economic reliance on gaming and casinos in Macao, the majority of studies on tourism in Macao have focused on its gaming sector. For instance, Deng, Gu, Law, and Lian (2020) compared determinants of the performance of the gaming sector in Macao against those of Las Vegas. Their findings indicate that the performance of the gaming sector in Macao is heavily reliant on the economic conditions of mainland China as well as VIP services and promotional marketing, whereas Las Vegas' tourism drivers are primarily non-gaming activities and slot machines. Attitudes of residents towards the sector have also impacted the direction of the development of the gaming industry, Harrill, Uysal, Cardon, Vong, and Dioko (2011) examined the attitudes of local residents towards gaming developments in Macao and identified supporting and opposing groups with distinctive characteristics. Supporters saw the gaming sector as a major source of economic growth for Macao, while opposing residents expressed concerns over safety and social issues (Harrill et al., 2011), such as 'changing values of teenagers, the high student drop-out rate, problem gambling and crime, changing family relationships, increasing tension between public needs and casino land requirements, traffic congestion, and air and noise pollution' (Wan, 2012, p. 737).

Driven by these concerns over gaming development, the government of Macao implemented a diversification policy intended to develop non-gaming components of the city's economy. McCartney (2008) considered the potential of the meetings, incentives, conventions, and exhibitions (MICE) industry to complement the gaming sector, with the aim of expanding the Macao tourism market into a diversified leisure and entertainment centre. In contrast, Vong (2016) applied a cultural tourist typology to the Macao tourism market and sought to investigate the feasibility of developing a cultural tourism identity for Macao's inbound tourism market. On the eve of the pandemic, Macao government had also established several initiatives to promote multiple non-gaming dimensions of tourism development, such as "City of Gastronomy" and "Asia top MICE destination".

The COVID-19 pandemic and the government of Macao's subsequent health and mobility measures halted growth of the tourism industry, resulting in losses of billions of dollars. McCartney (2021) summarised a three-wave analogy of Macao's reaction to the coronavirus pandemic: the first wave (22 January to 14 March 2020) involved a tourism lockdown in response to the COVID-19 outbreak; the second wave (15 March to early April of 2020) involved more stringent lockdowns in response to imported cases of COVID-19; and the third wave (early April of 2020 and thereafter) involved easing border restrictions to promote tourism recovery. Scholars and stakeholders are divided on whether recovery should involve the joint efforts of both the government and industry players, with significant consolidation and collaboration (McCartney, 2021). In a survey of local stakeholders, Im, Lam, and Ma (2021) identified the appropriateness of measures, decision timeliness, and government proactivity as three major factors for determining the effectiveness of crisis management strategies. Strategies with high scores in these areas not only facilitate economic productivity, which is essential for successful recovery, but stabilise the emotional and psychological states of residents and enable a smoother recovery process.

2.2. Input-output table and tourism satellite account

In the 1930s, Professor Wassily Leontief, an American economist, proposed an I-O model based on a general equilibrium model to analyse the economic structure of the United States (Leontief, 1936). Since then, the I-O model (or I-O table) has appeared frequently in economics studies, such as studies by Fan and Liu (2021), who adopted a multi-region I-O table to analyse the dynamics of the global supply chain, and by Xiao (2020), who investigated the input cost and output efficiency of the logistics industry in China using an I-O model. Using a multi-region I-O linear programming model, He, Ng, and Su (2019) analysed the economic resilience to power interruptions in multiple regions of China. The number of relevant studies on Macao are limited, however, given the lack of an official I-O table. While Chen and Song (2019) utilized an I-O model in their analysis of industrial links within the Macao gaming industry, few studies on Macao have constructed an I-O model.

Although the power of an I-O table is demonstrated in the economic analysis of inter-industrial dynamics, the standard of industrial classifications is usually fixed. The common standard is the System of National Accounts established by the United Nations (UN, 2008a). As the tourism industry is complicated by its position at the intersection of traditional industries, it is not independently listed in the national accounting system of the UN. To account for the contribution of the tourism industry to the economy, the UN and Member States proposed the TSA concept. In the early 1970s, France first developed the idea of using a 'satellite account' to highlight the position of the tourism industry in its economy. The TSA framework has since been revised and developed, with a formalised version proposed by the UN Statistics Division in 2000 in collaboration with the World Trade Organization (WTO), the Organization for Economic Cooperation and Development (OECD), and Eurostat. Stakeholders conducted an additional revision in 2008, which produced the current version of the TSA methodological framework (UN, 2008b).

Academic research has primarily used the TSA concept to investigate methodological developments and improvements (Frechtling, 2010; Smeral, 2006), implement the TSA in various regions (Libreros, Massieu, & Meis, 2006; Sharma & Olsen, 2005), analyse the impact and implications of economic structure (Ahlert, 2008; Dwyer, Forsyth, & Spurr, 2004), develop a web-based regional TSA information system (Jones & Munday, 2007), and examine the impact of tourism (Jones & Munday, 2004; Wu, Liu, Song, Liu, & Fu, 2019). In terms of practical applications, governments have used the TSA to account for and measure the impact of the tourism industry on the economy of their jurisdictions.

2.3. Dynamic stochastic general equilibrium model and shocks

A TSA illustrates the contributions of the tourism industry to the economy, whereas general equilibrium models describe and analyse the mechanism through which the tourism industry interlinks and interacts with other parts of the economy. Among general equilibrium models, computable general equilibrium (CGE) models utilise actual economic data to simulate the operation of economic systems and provide recommendations based on the simulation of models (Dixon & Jorgenson, 2012). In the literature on tourism, CGE models are widely used to assess the impact of various shocks to the tourism industry and the economic systems of tourism destinations. Short-term shocks represent one primary area of analysis. For instance, Li, Blake, and Cooper (2011) analysed the impact of the 2008 Beijing Olympics on the inbound tourism market of China and the economies of the Olympic Games destinations. They identified a positive ex ante impact and a negative ex post impact on the international tourism revenue of China for the year that the Olympics took place. This estimation was inconsistent with other similar studies, which generally reported the Olympic Games as having a positive impact on the host countries. Li et al. (2011) attributed this inconsistency to the change in Chinese visa policies that took place around the same time as the 2008 Olympic Games in Beijing. They found that the visa and travel policies of Olympics host destinations play a critical role in facilitating the full enjoyment of tourism benefits from hosting the Olympic Games. Similarly, Yang and Chen (2009) investigated the negative impact of the severe acute respiratory syndrome (SARS) epidemic on the tourism industry and the economy of Taiwan, China. They identified consumption by inbound visitors as a critical channel responsible for significant drops in GDP and employment during the epidemic. Meanwhile, Blake and Sinclair (2003) analysed the United States response to the September 11th attacks and assessed the effectiveness of various crisis management policies.

General equilibrium models can also assess the long-term or permanent impact of policies and crises. For example, Ponjan and Thirawat (2016) evaluated the long- and short-term impacts of tourism tax cuts on the tourism industry and economy of Thailand. They found that tourism tax cuts have a positive impact in terms of trade and GDP stimulation and identified inclusive fiscal policies as a critical condition for accruing long-term benefits. Meanwhile, Li, Liu, and Song (2019) used a CGE model to demonstrate the strong spillover effect of international tourism on non-tourism sectors and recommended tourism as an effective tool for supply-side structural reform in China.

Although CGE models are frequently adopted for policy evaluations (Li et al., 2019; Ponjan & Thirawat, 2016), the model itself is not designed for forecasting purposes (Her Majesty's Revenue & Customs (HMRC), 2013). The CGE model focuses on medium- to long-term macroeconomic analysis, while the DSGE model places greater emphasis on fluctuations across business cycles and uncertainty about the future (HMRC, 2013). As a macroeconomic model, the DSGE model takes future uncertainties and shocks into consideration and treats the model dynamics of these uncertainties and shocks with agent expectations of macroeconomic outcomes. The DSGE model can be incorporated into both exogenous and endogenous economic growth models (Liu, Song, & Blake, 2018). Using a two-sector dynamic model with stochastic productivity shocks, Liu et al. (2018) investigated the contributions of the tourism industry to economic growth in Mauritius, Spain, New Zealand, and the United States. They found that productivity improvement in tourism plays a significant role in economic growth, with the price sensitivity of international tourists and the structure of the domestic-international tourism market moderating the relationship (Liu et al., 2018). Cao, Zhang, and Zhang (2021) built a multi-sector DSGE model to model the economic and environmental impact of carbon tax on the tourism system. The DSGE modelling framework has also been widely applied to evaluate policy effectiveness during crisis with uncertainties that are difficult to accommodate in static framework. Policies to mitigate the negative influences that have been proposed and simulated are often related to tax and subsidies that directly helps to retrieve the loss of household welfare during crisis (Yang, Zhang, & Chen, 2020). Zhang and Yang (2018) adopted the DSGE framework to investigate the effects of inbound tourism on national economic account and simulated the effect of two strategies to mitigate the negative effect of Dutch disease on the tourism system. In terms of pandemic-related studies more recently, Yang et al. (2020) adopted a DSGE model incorporating health status and health disaster indicators to capture the early impact of the COVID-19 pandemic on household welfare at tourism destinations. They found that tourism stimulation policies can facilitate sector recovery in exchange for a decline in household welfare, especially in health-related aspects.

Scholars have established that the TSA and DSGE models are effective tools for understanding and assessing the links between the tourism industry and the local economy. The DSGE modelling framework is particularly appropriate for generating policy simulations in the post-

Table 1
Sample structure of the constructed I-O table.

INPUT OUTPUT		Intermediate demand			Final demand							Export	Import	Total output
		Restaurant & similar activities	…	**Total intermediate demand**	Final consumption			Capital formation			**Total final demand**			
					Residents' consumption	Government consumption	**Total final consumption**	Fixed capital formation	Inventory increase	**Gross capital formation**				
Intermediate input	Restaurant & similar activities	853	…	**5907**	10,205	0	**10,205**	0	3729	**3729**	**13,934**	**177**	**16,514**	**3506**
	…	…	…	**…**	…	…	**…**	…	…	**…**	**…**	**…**	**…**	**…**
	Total intermediate demand	**2329**	**…**	**188,577**	**105,746**	**42,064**	**147,810**	**74,193**	**2202**	**76,392**	**224,202**	**362,505**	**147,678**	**627,609**
Value added	Compensation of employees	779	…	**120,617**										
	Taxes on production	13	…	**125,254**										
	Operating surplus	385	…	**193,158**										
	Total value added	**1177**	**…**	**439,029**										
Total input		**3506**	**…**	**627,609**										

Unit: Million MOP.

COVID-19 era for small open economies that are assumed to be of negligible size relative to the world economy (Beltran & Draper, 2008) and show clear connections across multiple agents but are vulnerable to external shocks. Such research on Macao, however, is limited. Thus, in line with all DSGE studies focusing on small economies, this study adopts the DSGE framework to evaluate the transmission mechanism of the tourism and economic system in Macao. Empirical analysis using data on Macao would not only provide further empirical evidence for future studies but would provide industry stakeholders and government officers in Macao with essential information for planning recovery strategies.

3. Tourism satellite account analysis

3.1. *Input-output table*

Based on data published by the DSEC (2020b), Macao's industries fall into 17 categories: mining and quarrying; manufacturing; electricity, gas, and water supply; construction; wholesale and retail; hotels and similar activities; restaurants and similar activities; transport, storage, and communications; banking; insurance and pension funding; real estate activities; renting and business activities; public administration; education; health and social work; gaming and junket activities; and other community, social, and personal services. This study compiles the input-output table of Macao using the non-survey method. According to the characteristics of Macao's industrial structure and the existing statistical data, the number of sectors in the input-output table is further extended and determined to be 22. In particular, "manufacturing sector" is further specified into six sectors, namely food and beverage manufacturing, textile, clothing, media and printing, cement and concrete, and other unspecified manufacturing sector. "Electricity, gas, and water supply" is further divided into two sectors such as the production and distribution of electricity, gas, and steam, and the production and distribution of water. The main compiling ideas are: based on the available sectoral data in the Macao Statistical Yearbook, the inter-industry technical coefficient of Macao in the EORA26 database (26 sectors in 2015), and the coefficient of the input-output table of the neighbouring Guangdong Province (142 sectors in 2017), we used RAS method to calculate the input-output table of Macao in 2018 (Wiebe & Lenzen, 2016).

The process of constructing the I-O table is as follows: (1) collecting sectoral data on total output, initial input (value added), and intermediate consumption from the statistical yearbook; (2) on the basis of sectoral structural ratio from the statistical yearbook, the total data of the sub-item (final use) in the GDP accounting of expenditure method is allocated to each sector. Meanwhile, the sectoral total intermediate use can be obtained according to the relationship "intermediate use + final use = total output"; (3) EORA26 shows the technical coefficient between 26 sectors in Macao, which is used as the initial value of the intermediate flow coefficient of the same and similar sectors in the input-output table designed by us, while the initial value of the coefficient of the missing or different departments is replaced by the technical coefficient of the similar sectors in the input-output table of 142 sectors in the neighbouring Guangdong Province (Hewings, 1977); (4) the intermediate flow matrix between sectors calculated by the RAS method is combined with the initial input and final use matrix to form a standard form of an input-output table; (5) testing the balance of the constructed I-O table and adjust accordingly.

Following the guidelines of the *Input-Output Tables of China* (National Bureau of Statistics of China, 2012), the final I-O table for Macao includes five sections: (1) total output, which is the value of all goods and services produced by Macanese residents (including both newly created and intermediate products) and the value of fixed assets transfer; (2) intermediate investment, which is the value of all non-fixed assets and services used in the production processes of local residents; (3) value added, which reflects the added value created during the production process, such as employee compensation, operating surplus, and taxes on production; (4) intermediate demands, which refers to the value of all non-fixed assets and services required in the production processes of local residents; and (5) final demand, which includes the final consumption expenditure within Macao. The constructed I-O table for the Macao economy reflects the interrelationship among various sectors and serves as a basis for subsequent analyses of the TSA and the general equilibrium model. Table 1 illustrates the sample structure of the constructed I-O table for the Macao economy. The complete version of the I-O table is presented in the Appendix.

3.2. Tourism satellite account

The Macao SAR government publishes an annual TSA to outline the contributions of the tourism industry to the Macao economy. Although the published results provide rich information, the methodology is limited in scope and rigor. The construction of the TSA of Macao involves investigations on both the demand- and the supply-sides, with the interrelationships among the sectors derived from the I-O table, however, the official TSA generated by the government of Macao focuses on primary data from the demand- and supply-sides without a thorough examination of the I-O framework. This creates several drawbacks. First, the official TSA includes only a limited number of sub-sectors of the tourism industry, specifically gaming, retail, dining, accommodation, transportation, and travel agencies. Other related sub-sectors, such as insurance, the postal service, sightseeing, and leisure activities, are not considered. Second, the official TSA does not include the I-O table and as such, neglects the interrelationships between tourism and non-tourism industries. Consequently, the TSA overestimates or underestimates the economic contributions of the tourism industry.

Through this study, we intend to complement the official TSA generated by the government of Macao and emphasise the demand-side data. A tourist expenditure survey was conducted through a professional marketing research company in December 2021. A total of 4000 invitations were sent with 1011 valid responses received. Of the responses, the survey included 750 responses from the Chinese Mainland, 208 responses from Hong Kong SAR, and 53 responses from Taiwan, China. The structure of the sample was largely reflective of the source market structure of the inbound tourism market of Macao. The target respondents were individuals who travelled to Macao in 2019. The survey questionnaire asked the respondents about their travel experience in Macao, and specifically to report their total expenditure during their trip as percentage shares of different categories. The categories included expenditure on travel agencies outside of Macao, travel agencies within Macao, transportation, accommodation, food and beverages, gaming, admission to attractions, entertainment activities, and shopping. Several of these categories had subcategories with further question subdivisions. For example, the survey asked the respondents to declare the shares of transportation expenditure for buses, taxis, rental cars, and fuel; the shares of admission fees to attractions for natural attractions, cultural attractions, and other exhibitions; and the shares of entertainment spending for theme parks, artistic performance, golf, and other activities. This study triangulated the accuracy of the survey data by comparing the aggregated expenditures of different categories with government released reports and statistics (DSEC, 2020a). Given that the proportions of most major expenditure categories (e.g., shopping, accommodation, food and beverage, and transportation) reflected the government data, we conclude that the survey data have a high degree of accuracy in describing the expenditure allocation of tourists travelling to Macao before the COVID-19 pandemic.

Visitors' direct consumption within a sector is calculated using the survey data and the government statistical data. These consumption values constitute the direct contribution of tourism to this specific sector and the economy. The indirect contribution of tourism to the economy arises from the interrelationship among various sectors. That is, in order to satisfy tourism demand, the destination economy not only needs to produce the corresponding goods for final consumption, but also is required to produce the intermediate products that would be utilized throughout the production process. The I-O table constructed in section 3.1 allows the calculation of the amount of such intermediate products. The aggregation of the direct and the indirect contributions of tourism to a specific sector provides the total contribution of tourism to a specific sector. A tourism ratio statistic can be calculated by dividing the total contribution of tourism in a sector to the total volume of production in that sector, which describes the reliance of certain sector on tourism activities (Table 2). The tourism ratio of the gaming sector is the highest at 81%, followed by the passenger transportation sector at 73%, retail at 67%, food and beverages at 68%, and accommodation at 53%.

Table 2
Tourism ratio by tourism goods and services.

Category	Tourism ratio	
	Our estimates	Government TSA
Gaming	81%	98.7%
Passenger transportation	73%	66.2%
Retail	67%	52.5%
Food and beverages	68%	47.8%
Accommodation	53%	43.3%
Banking	1%	–
Insurance	4%	–
Postal service	10%	–
Non-tourism products	1%	–

The TSA results of this study are cross-referenced against the official TSA published by the Macao SAR government. Although the results for most sectors are close, there are discrepancies in the results for some sectors. For example, the tourism ratio of the gaming sector is approximately 81% by our estimation, whereas the government estimate is as high as 98.7%. According to our estimation, the tourism ratios of the food and beverages and the accommodations sectors are 68% and 53%, respectively, but the government figures are 47.8% and 43.3%, respectively. These discrepancies can be attributed to methodological differences. For instance, the government TSA relies on primary data from the demand and supply sides, which overestimates some of the transactions that flow through gaming operators and travel agencies and underestimates the interrelationship among sectors. In contrast, we complement the government's TSA by investigating the structure of the economy within an I-O framework. One drawback of this approach is the difficulty in reaching VIP gamblers through a regular survey – and their contribution to gaming revenue is substantial in Macao. This methodological limitation is likely the reason for our low tourism ratio for gaming.

In addition, the supply-side data underestimates the contribution of tourism through the transportation, shopping, food and beverages, and accommodation sectors, which is reflected in the relatively low tourism ratios in the government TSA. Although both perspectives contain biases and cannot fully capture tourism expenditure, both estimates should be considered in the decision-making processes of the tourism industry and the government.

In addition to these sectors, which are closely related to tourism activities, our TSA results also provide the estimation of tourism ratios in 'non-tourism' sectors, which are omitted from the government TSA. For example, tourists contribute around 10% of the GDP for the postal service sector. While retail tourism has become increasingly important in many destinations, tourists do not usually carry their souvenirs around during their trip. Postal and delivery services provide a convenient option for tourists to continue their trip without the burden of excessive luggage. To protect both their luggage and person, insurance is also frequently provided to offer a safer tourism experience. According to our estimation, around 4% of the GDP generated in Macao's insurance sector is attributed to tourists and inbound tourism activities, contributing around MOP23 million to the local economy.[1]

[1] This figure does not include those who visit Macao with the primary purpose of purchasing insurance.

Finally, we estimate that the tourism industry contributes 35% of the value added to the Macao economy in contrast with the contribution of 50.5% reported by the government TSA. Given that we omit the contribution of VIP gamblers on the demand-side, we inevitably underestimate tourism revenue and the value added. Nevertheless, due to the lack of an I-O table, the official TSA cannot split the value added of other sectors from that of the tourism sub-sectors. For example, the construction of a new hotel should be accounted for under the construction sector, but cannot be achieved in the government version of the TSA. Thus, the government TSA overestimates the value added. We recommend that the two values be treated as lower and upper bounds of the real tourism value added, and both values should be considered in assessing the contribution of tourism to the Macao economy.

4. Dynamic general equilibrium model

4.1. The model

In this study, we established a two-sector artificial economy (i.e., an economic system designed to simulate interactions of agents) with the supplement of a public services sector and a private land rental to relax the assumption of diminishing returns of capital and to integrate a new growth theory. Three types of agents (i.e., households, firms, and the government) and three sectors (i.e., tourism, non-tourism, and public services) reside in this artificial economy. This comprehensive framework built within the DSGE model can reflect the complex relationships between key economic variables and tourism variables appropriately in the system. The transmission mechanism modelled within the DSGE framework also enables the following policy simulation practices by impulse response analysis to simulate the impact of potential policies on a series of key economic and tourism indicators, and finally project the influences to the tourism contribution to the economy.

According to neoclassical microeconomics, households maximise the discounted value of their lifetime utility for consumption and leisure in a constrained income budget, including wages and rents from renting their leisure time and private land to firms as a trade-off (Liu & Wu, 2019). A representative household member's behaviour can be described by maximising the following utility function:

$$U = E_0 \sum_{t=0}^{\infty} \beta^t \frac{1}{1-\sigma}\left[(C_t - hC_{t-1}) + \frac{{u_t}^{1+v_1}}{1+v_1} + \frac{\left(La_{l,t}\zeta_{la,t}\right)^{1+v_2}}{1+v_2}\right]^{1-\sigma} \tag{1}$$

where a household's utility is generated by consumption (C_t), leisure (measured by time of unemployment, u_t), and private land ($La_{l,t}$). The exogenous variable $\zeta_{la,t}$ is an auto-regression process capturing the impact of private land on the economy. Households can either rent their time or land to firms as production factors and gain wages or rent, respectively. E_0 is the expectation operator, β is the discount rate, h is a parameter that governs the habit persistence of consumption, and σ, v_1, and v_2 are model parameters of a constant elasticity of the substitution (CES) function.

Firms aim to maximise the discounted value of profits, defined as added value minus physical and labour capital after taxation. The tourism and non-tourism firms are assumed to exhibit the Cobb-Douglas production function, described as follows:

$$Y_{T,t} = \Omega_{T,t} K_{T,t}^{\alpha_1} N_{T,t}^{\alpha_2} La_{T,t}^{1-\alpha_1-\alpha_2}, \tag{2}$$

$$Y_{NT,t} = \Omega_{NT,t} K_{NT,t}^{\alpha_3} N_{NT,t}^{1-\alpha_3}, \tag{3}$$

where $Y_{T,t}$ and $Y_{NT,t}$ are the value added of tourism and non-tourism sectors in time t, respectively. $K_{T,t}$ and $K_{NT,t}$ are physical capital following evolution processes as follows:

$$K_{T,t+1} = I_{T,t} + (1-\delta)K_{T,t} \text{ and } K_{NT,t+1} = I_{NT,t} + (1-\delta)K_{NT,t}, \tag{4}$$

where $I_{T,t}$ and $I_{NT,t}$ are physical capital investments in tourism and non-tourism sectors, respectively, which are the summation of domestic and foreign direct investments in each sector. δ is the depreciation rate. $La_{l,t}$ is differentiated from typical physical capital and represents the private land rent to the tourism sector to develop attractions and sight-seeing activities.

The productivity of tourism and non-tourism sectors are assumed to be related to the externalities of physical capital in its own sector ($K_{T,t}$ and $K_{NT,t}$) and the public sector ($K_{P,t}$), as well as the provision of public services ($Y_{P,t}$):

$$\Omega_{T,t} = A_t A_{T,t} \left(\zeta_{P,t} Y_{P,t}\right)^{\varphi_{P,T}} K_{T,t}^{\varphi_T} \left(\frac{K_{P,t}}{K_{T,t}+K_{NT,t}}\right)^{\varphi_{C,T}}$$

and

$$\Omega_{NT,t} = A_t A_{NT,t} \left(\zeta_{P,t} Y_{P,t}\right)^{\varphi_{P,NT}} K_{NT,t}^{\varphi_{NT}} \left(\frac{K_{P,t}}{K_{T,t}+K_{NT,t}}\right)^{\varphi_{C,NT}} \tag{5}$$

where $A_{T,t}$ and $A_{NT,t}$ represent the auto-regression process of sectorial productivity and A_t represents total productivity; $\zeta_{P,t}$ is an exogenous shock to the spill-over effect of public services provision; the ratio between $K_{P,t}$ and $\left(K_{T,t}+K_{NT,t}\right)$ describes the diminished spill-over effect of public physical capital when the congestion occurs on public services by the private sector. φ is a set of parameters governing the magnitude of spill-over effect of various capitals and public provisions on sectorial productivities.

Labour inputs in two sectors, $N_{T,t}$ and $N_{NT,t}$, are the product of labour forces, $n_{T,t}$ and $n_{NT,t}$, and human capital, H_t. Following Arrow (1962) learning-by-doing hypothesis, H_t evolves as follows:

$$H_t = \frac{EX_{T,t}^{a_T}\left(Y_{T,t}-EX_{T,t}\right)^{b_T}\xi_{H,t}}{H_t^{\pi_T}} + \frac{EX_{NT,t}^{a_{NT}}\left(Y_{NT,t}-EX_{NT,t}\right)^{b_{NT}}}{H_t^{\pi_{NT}}} - \delta_H H_{t-1}, \tag{6}$$

where $EX_{T,t}$ and $EX_{NT,t}$ represent exports in tourism and non-tourism sectors, respectively. Therefore, products being exported (EX_t) and domestically consumed $(Y_t - EX_t)$ jointly contribute to human capital accumulation in the form of innovation. $\xi_{H,t}$ is an exogenous shock in human capital accumulation, δ_H is the depreciation rate of human capital, and a, b, and π are model parameters.

The exports in both tourism and non-tourism sectors are determined by global income ($Y_{ROW,t}$), exchange rates (ER_t), and price levels ($P_{T,t}$ and $P_{NT,t}$):

$$EX_{T,t} = \left(\frac{P_{T,t}}{ER_t}\right)^{\theta_T} Y_{ROW,t}^{\omega_T} \text{ and } EX_{NT,t} = \left(\frac{P_{NT,t}}{ER_t}\right)^{\theta_{NT}} Y_{ROW,t}^{\omega_{NT}} \tag{7}$$

The government, however, aims to balance government revenue – including taxes on wages and production and the sale of treasury securities – against government expenditures typically used to pay the principal and interest of government-issued bonds (Liu et al., 2018). The production of public services is described by the Cobb-Douglas process as follows:

$$Y_{P,t} = A_{P,t} K_{P,t}^{\alpha_4} N_{P,t}^{1-\alpha_4} \tag{8}$$

The model is closed by applying the Taylor rule, as seen in Liu et al. (2018) and Liu and Wu (2019). The DSGE model used in this study captures the dynamics of the three sectors to optimise their behaviours under a general equilibrium framework. Fig. 1 illustrates the circular flow of the model.

4.2. Model calibration

Liu et al. (2018) introduced the DSGE model to the tourism field and

Liu and Wu (2019) further extended the model into a more robust framework. Three types of parameters are included in the modelling framework: structural parameters, shock parameters, and steady state values. The estimated structural parameters reflect the relationships between different variables in the system. Shock parameters simulate the shock imposed on the system. Steady state values are determined using official macroeconomic statistics (i.e., GDP, exports, and imports data obtained from the Statistics and Census Service of Macao) and TSA aggregates to calculate the share of the contribution from tourism in various sectors to reflect the current situation in Macao (Table 3). We conventionally determined structural parameters from previous studies in the literature on DSGE (Bhattarai & Trzeciakiewicz, 2017; Orrego & Vega, 2013), similar to the approach adopted by Liu et al. (2018). We discuss shock parameters in the next section.

Table 3
Steady state values in the DSGE model.

Indicator	Variable	Value
c_s	share of consumption	0.358
i_s	investment steady state	0.211
yt_s	share of tourism GDP	0.72
u_s	unemployment rate	0.019
ct_s	share of tourism consumption	0.358
cnt_s	share of non-tourism consumption	0.114
cp_s	share of public sector consumption	0.241
cm_s	share of imports	0.336
cmt_s	share of tourism imports	0.077
cmnt_s	share of non-tourism imports	0.259
ext_s	share of tourism exports	0.014
exnt_s	share of non-tourism exports	0.294

Note: These values are calculated from macro data and TSA aggregates.

4.3. Impulse response

To investigate potential relief policies amidst the COVID-19 pandemic, we ran a baseline simulation and two policy simulations using the DSGE model established in the previous sections. The baseline simulation reflects the trend of the variable under the shock of the COVID-19 pandemic (Fig. 2), and the simulation results show a 65% decrease in GDP, which is similar to the actual situation in Macao during the pandemic. Fig. 2 shows that the health shock leads to a significant drop in GDP, tourism consumption, and exports, whereas there is a short-term increase in consumption resulting from panic purchasing. There is a significant drop in productivity in both the tourism and non-tourism sectors, along with a decrease in employment in both sectors. It takes approximately 5 periods (years) for the economy to see considerable recovery and approximately 10 periods for the economy to recover to a steady state once the health shock is relieved, with the majority of the variables converging back to their pre-shock levels. In our model, the recovery to steady state segment is not the same as the recovery to the pre-COVID-19 level. Given that the economy of Macao was experiencing a growing trend powered by innovation in productivity in 2019, the recovery in Figs. 2, 3 and 4 refers to a state that assumes the COVID-19 pandemic did not occur.

A significant drop in tourism consumption is observed at the initial stage of the pandemic. This is due to the absence of foreign tourists because of border control policies and cautious behaviour by local residents. Nonetheless, local residents would allocate their income to non-tourism consumptions to maintain a certain level of utility. Tourism consumption sustains the economy only for a couple of years and starts recovery sooner than other variables. This is due to the change in consumption bundles of local residents. In reality, due to the combined force of government consumption vouchers and effective promotion of staycation packages, Macao residents benefited from local tourism activities, which mitigated the loss of tourism revenue due to the border lockdown.

In terms of employment, the drop is far more severe than the unemployment rate of around 3% to 4% that was present in Macao throughout the pandemic. Nevertheless, employment in our model assumes representative households with similar endowments and without differentiation in terms of positions and rankings. Since the beginning of the pandemic, the integrated resorts in Macao dismissed many medium-to-high ranking managers to keep the lower ranking employees within the firm. These medium-to-high ranking managers should be translated

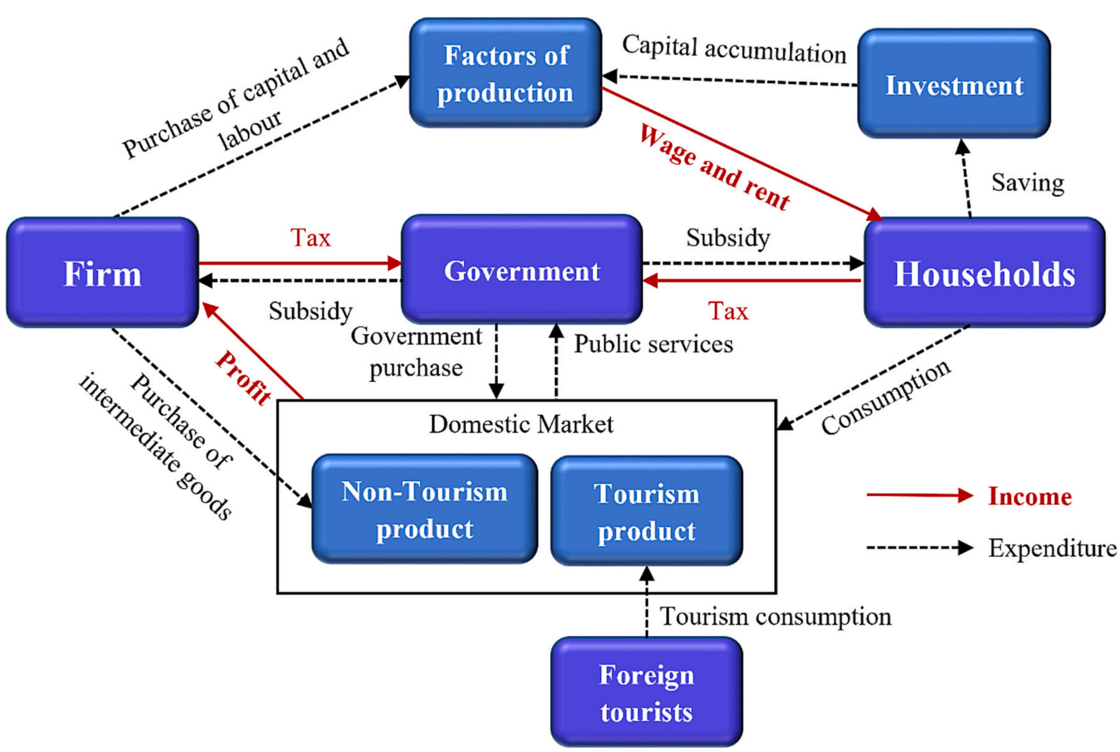

Fig. 1. Circular flowchart of the model.

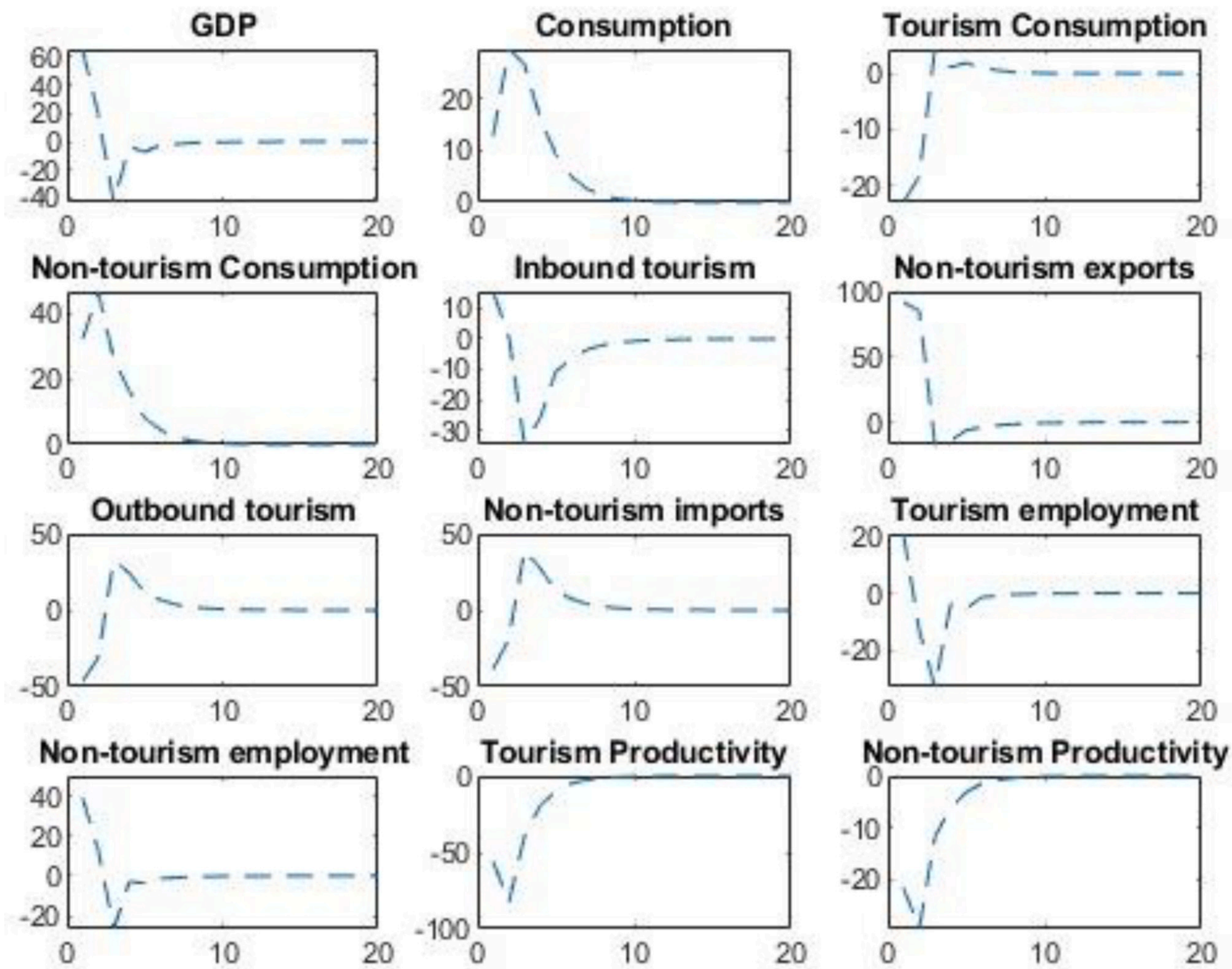

Fig. 2. Impulse response functions (IRFs) under COVID-19 (baseline).

into multiple representative employees in the model due to their original high income and consumption levels. Alternatively, if the integrated resorts kept these medium-to-high ranking managers and dismissed low-level employees, the unemployment statistics would have been much worse.

The first policy simulation considers a tax reduction, which supports businesses by reducing their tax liability. In the impulse response analysis, the tax reduction shock was simulated empirically by reducing the tax rate imposing on firms specifically. This simulated policy will then affect key variables in the economic system, including GDP, consumption and firm-level productivity (i.e., tourism and non-tourism), which further influence the overall tourism contribution to the economy. The shock of the tax reduction on firms is simulated through a 20% decrease in the tax rate in the system. Fig. 3 presents an illustration of the impulse response functions (IRF) of the key variables in the first policy simulation. The solid blue lines represent the baseline simulation, which considers only the COVID-19 pandemic. The dashed red lines represent the IRFs with a tax reduction. Tax reduction appears to have a minor impact on IRFs in terms of mitigating the severity of the shock and speeding up recovery. With the sudden health shock of a health crisis, the economy is less likely to be rebooted effectively through tax reductions.

The second policy simulation also includes an increase in the disposable income of residents, but this increase is in the form of financial subsidies. The shock of the financial subsidy is simulated through a 20% increase in disposable income, representing a stimulation in consumption from the demand side. Similar to the first policy transmission mechanism, the financial subsidies shock will affect a series of key variables in the economic system due to the interrelations of the variables in the DSGE system. Fig. 4 presents an illustration of the IRFs of the key variables in the second policy simulation, with the solid blue lines representing the baseline simulation and the dashed orange lines representing the IRFs with financial subsidies. Based on the simulation results, giving financial subsides to residents can mitigate the severity of a health shock in the short-term. For instance, the drops in GDP, inbound tourism, non-tourism exports, and employment (both in the tourism and non-tourism sectors) are not as severe as they are in the baseline case. In comparison with tax reduction, which mainly helps firms to save cost and to survive throughout the pandemic, financial subsidies generally boost the purchasing power of the entire public and therefore provide stronger potential to mitigate recess and facilitate recovery. Similar to the tax reduction simulation, however, financial subsidies do not help the economy shift to a quicker recovery path. That is, financial assistance – in terms of both tax reduction and financial subsidy – helps the situation but cannot speed up the recovery of the economy from a health crisis such as the current COVID-19 pandemic.

5. Implications and conclusions

In this study, we explored the tourism sector of Macao during the COVID-19 pandemic by establishing a DSGE model. First, we generated an I-O table and a TSA to support the construction of the DSGE model.

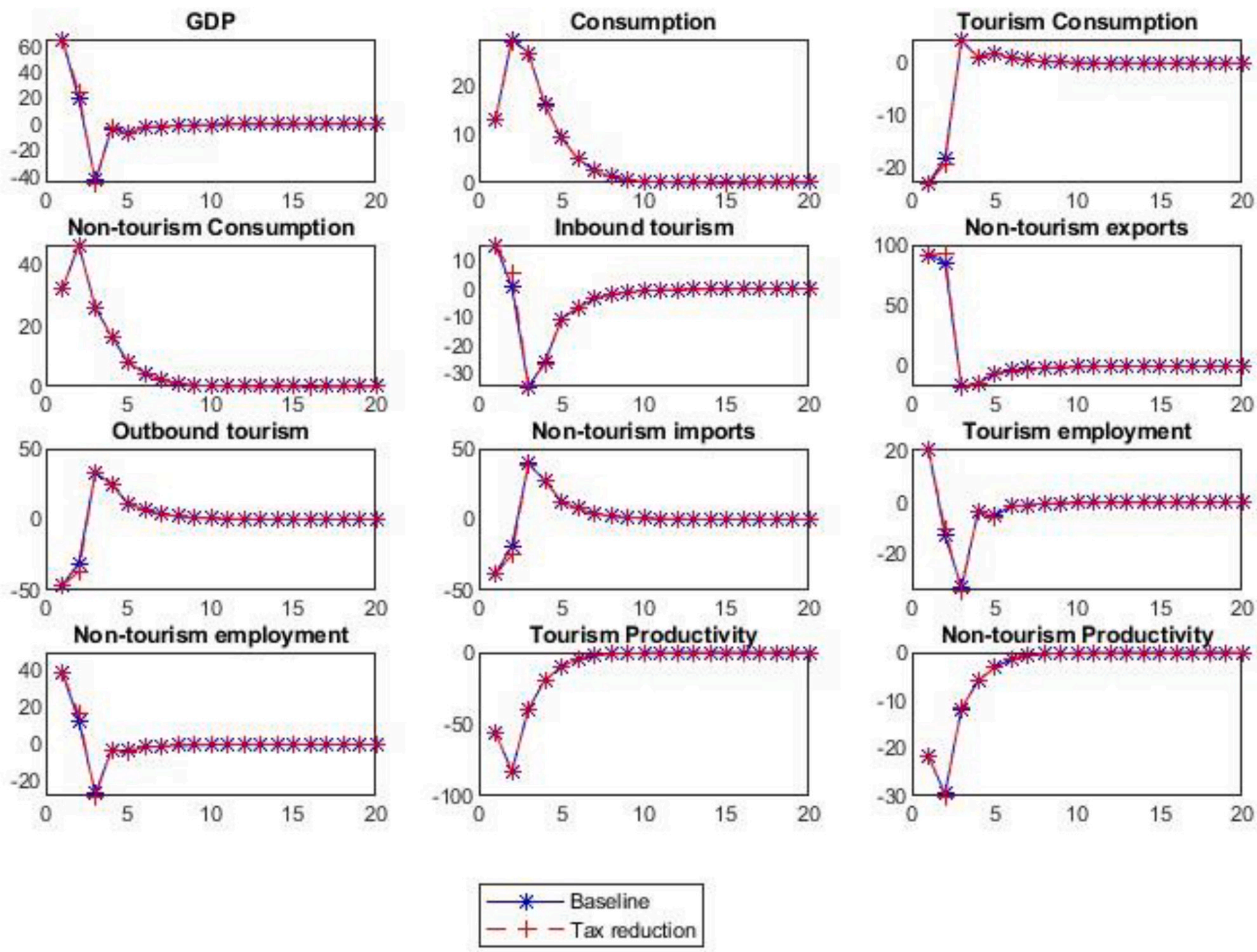

Fig. 3. IRFs under tax reduction.

Second, we ran two policy simulations to investigate the potential of different policies for mitigating the severity of the impact of COVID-19 and to speed up the recovery of the tourism industry and the economy after the pandemic.

Through our simulations, we found that both tax reduction and financial subsidies for local residents do not facilitate a quick post-pandemic recovery. Other policy measures should be considered to facilitate a quicker recovery. Against the severity of the COVID-19 pandemic and its enormous impact on Macao's economy, stimulation from the demand-side is not enough for a quick recovery. Supply-side policies, such as offering employment support and support to the capital chain, should be considered for reviving businesses and accelerating economic recovery.

While the simulated policies do not facilitate a quick recovery, the financial subsidy showed a significant mitigating effect on the severity of the impact of the COVID-19 pandemic. From an economic perspective, financial subsidies would allow all residents in Macao to maintain an economically significant level of consumption. Limiting the subsidy to a period-wise use (e.g., residents can use a fixed percentage of the total subsidy per week) can further smooth the consumption pattern. This solution is currently in use in Macao and consumption subsidies have proven effective in many other scenarios (Yang et al., 2020).

In contrast to financial subsidies, the effectiveness of tax reductions is limited. In a health crisis situation such as the COVID-19 pandemic, a significant drop in employment is unavoidable, and occurred both in our simulation and in reality. Therefore, tax reductions help only those who remain employed, and the amount of disposable income provided by a tax reduction increases monotonically with a resident's income. In essence, the support provided is distributed unevenly, with the tax reduction subsidy rendering more help to residents with less need for it, whereas unemployed residents are trapped at a relatively low consumption level without benefitting from the policy. Furthermore, in practice, a tax reduction is often implemented as a tax rebate at the end of the year, which does not have an instant and smoothing effect on mitigating the impact of the COVID-19 pandemic.

Our simulation results further confirm the effectiveness of a consumption subsidy policy for Macao with respect to mitigating the severity of the economic impact of the COVID-19 pandemic. The DSGE model is generalisable and can be used to simulate different scenarios and assess the effectiveness of other policies for Macao. Other tourism destinations can also adopt this model and use parameter calibrations of their own for destination-specific simulations.

This study has its limitations. First, in constructing the TSA, we primarily considered ordinary tourists and largely omitted the contribution of VIP gamblers to Macao's gaming revenue. Although this drawback has some minor influence on the results related to the COVID-19 pandemic period, we encourage future studies to explore a more comprehensive approach to constructing a TSA for Macao. Second, we only investigated two major pandemic relief policies in this study, but there are other alternatives policies and qualitative factors that could have effects on the pandemic recovery. The simulation rates of the policies can be further explored as well in the future, to investigate the relationship between different policy levels and the response of the whole tourism system. We recommend that future studies consider other possible combinations of factors.

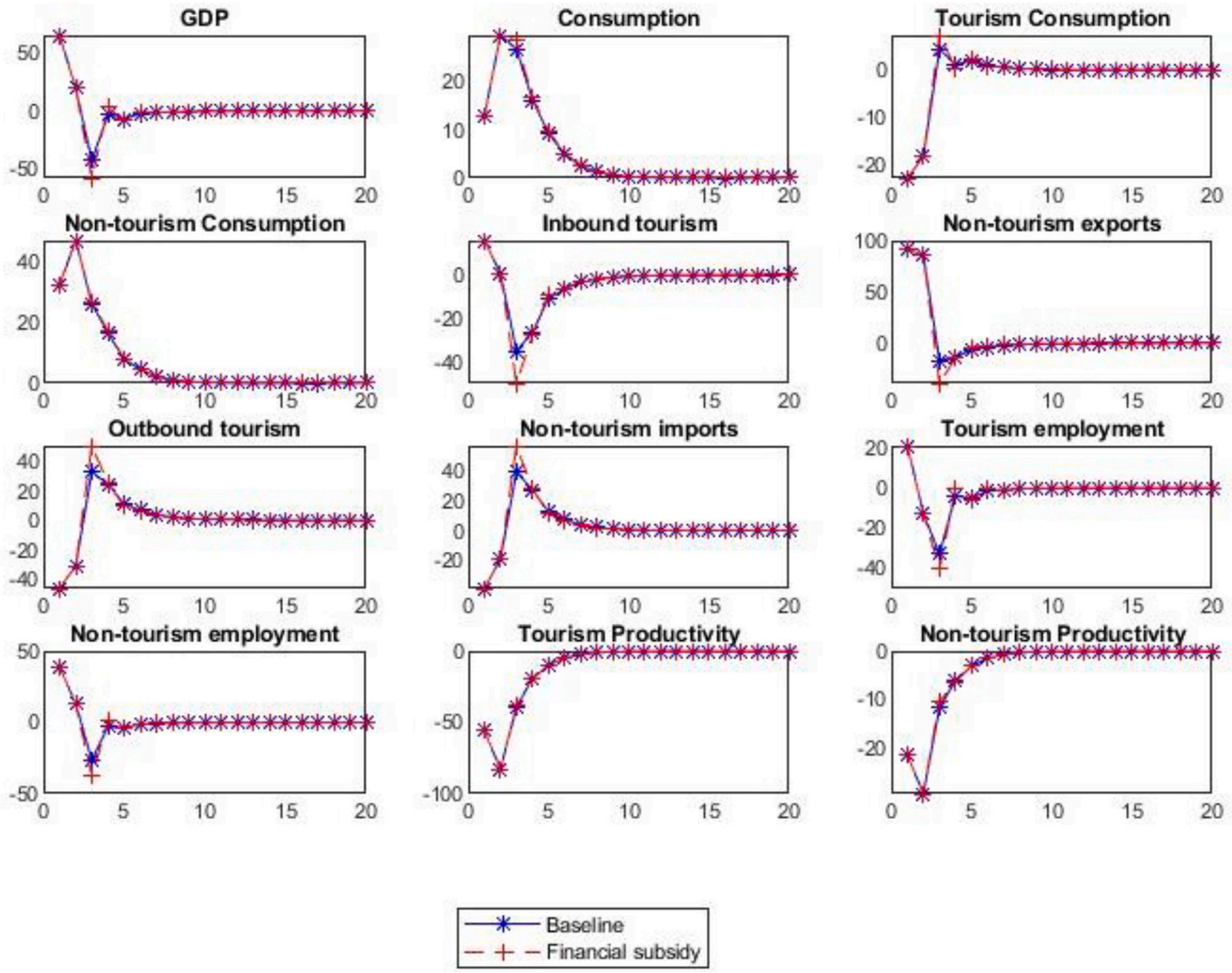

Fig. 4. IRFs under financial subsidy.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.annale.2023.100106.

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