

Article

The Potential Analytical Impact of Significant Sectoral Creative Economy on Thailand's Economy: A Case Study of the IRS-CGE Model vs. the CRS-CGE Model for Both the National and Provincial Economies

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Abstract: The United Nations has promoted and supported the UNCTAD Creative Economy Programme since 2004 to help countries around the world understand how to promote economic development through creativity in industries. This research article aims to determine whether the creative economy will be the major engine to accelerate Thailand's economic development in the coming decade or not, and what the major creative economy sectors are that must be prioritized or initiated and focused on. The data implemented in this research cover 2011–2018, which consist of creative economy sector income, the IO table, and the SAM table. The methodology utilized in this research was the ML model, the GREY model for predicting the growth rate of income from the major creative economy sectors contribute to Thailand's economy between 2019–2025, and the CGE model. The study's empirical findings show that the significant sectoral creative economy consists of fashion, advertising, Thai food, and cultural tourism, which need to be given more stimulus. Furthermore, the economies of Chiang Mai, and Thailand as a whole, would eventually be high-income economies if creative economy sectors were to be promoted and continuously supported by efficient policies. the economic growth of Thailand and Chiang Mai would eventually become high income whenever these economies allow creative economy sectors to be promoted or supported by efficient policies continuously.



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Keywords: creative economy sectors; Thailand's economy; Chiang Mai's economy; ML model; GREY model; prediction; CGE model; long-run growth

1. Introduction

The original concept of the creative economy was started by [Howkins \(2001\)](#). He suggested that the core idea of the creative economy is based on novel imaginative qualities rather than land, labor, and capital. Later, in 2004, UNCTAD endeavored to mold the world-wide perception of the creative economy with the aim of advancing economic development via creativity. Recently, the creative economy has been very interesting for many countries around the world. UNCTAD (United Nations Conference on Trade and Development) reported that in 2020 ([UNCTAD 2020](#)), exports of all creative services around the world are increasing every year between 2010–2020. In developing economies, exports of all creative services were around USD 80 billion in 2010 and approximately USD 188 billion in 2020. The developed economies' exports of all creative services in 2010 were around USD 420 billion; after that, in 2020, the developed economies' exports of all creative services increased to USD 877 billion. For the world economies, the total export was around USD 500 billion in 2010, which continuously increased until 2020; therefore, the world economies' exports of all creative services in this year increased to USD 1065 billion.

All creative goods exports have been increasing continually, year-over-year, as reported by UNCTAD in both developing economies and developed economies; in developing economies in 2002, these exports were valued at USD 80 billion, increasing to USD

296 billion in 2020. The developed economies were found to have dynamically increased from approximately USD 140 billion in 2002 to USD 229 billion in 2020.

Furthermore, UNESCO reported that the world's creative economy has grown very rapidly, and it has been confirmed that the creative economy contributes approximately 6.1% to the world's GDP every year (UNESCO 2023). Additionally, the world's creative economy is capable of generating an average income per year for the world's economy valued at USD 2250 billion, as well as creating nearly 30 million jobs globally.

For Thailand, the creative economy has played a significant role in driving Thailand's economy for over a decade. Furthermore, in 2018, Thailand began to accept the creative economy. Because the government of Thailand believes that the creative economy will be the core competency sector of future economic development, it has established the Creative Economy Agency (a public organization) to monitor and promote the creative economy, and be an accelerator of Thailand's economic development in the future. The Creative Economy Agency (CEA) reported that the creative economy has a high potential to become an important engine accelerating Thailand's GDP income. According to this reported finding, Thailand's creative economy contributes approximately 10% to Thailand's GDP per year on average, and also creates jobs for Thailand's labor market, which employs approximately 2% of Thailand's worker population. The creative economy of Thailand consisted of 15 creative economies, which typically include handicrafts, music, visual arts, performing arts, film, broadcasting, printing, software, advertising, design, architectural services, fashion, Thai food, traditional Thai medicine, and cultural tourism. These sectors have driven Thailand's economy for a long time (see Figure 1).

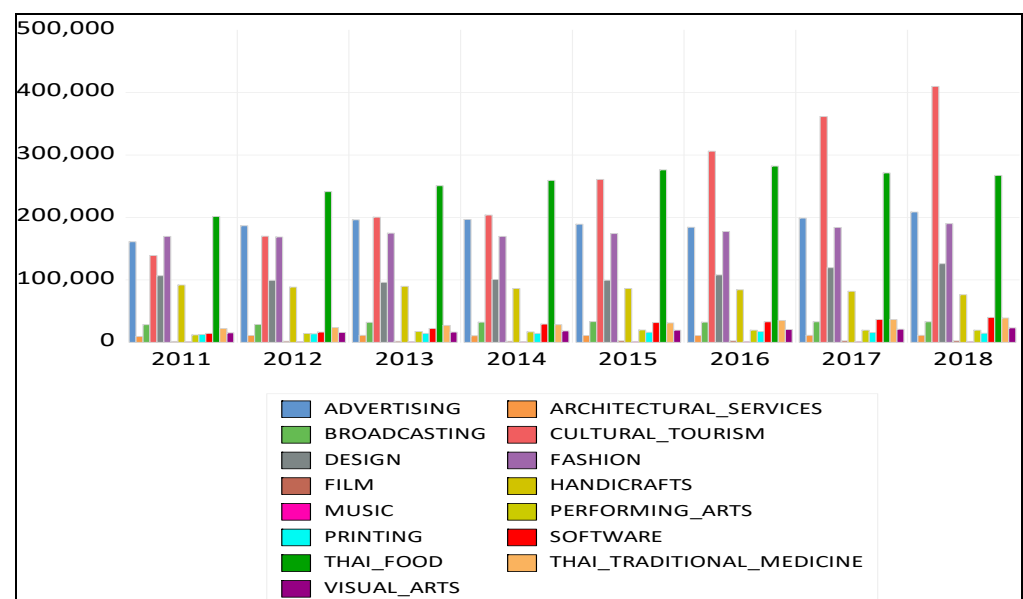


Figure 1. All the creative economy sectors that have generated income for Thailand's economy between 2011–2018. Unit: A Million baht (USD 28,256.57).

The top five creative economy sectors were ranked in Figure 2 according to how much money they contributed to Thailand's GDP. Cultural tourism is ranked first, Thai food is ranked second, advertising is ranked third, fashion is ranked fourth, and design are ranked fifth.

Based on these facts, the main aim of the study is to determine whether the creative economy will be the major engine to accelerate Thailand's economic development in the coming decade or not. If the creative economy will play an important role in driving Thailand's economy in the future, then which are the major creative sectors that must be prioritized or initiated to focus on?

The structure of this research article is as follows: The first section is an introduction and overview of creative economies around the world and Thailand. The second part is a literature review of creative economies. The third part is the conceptual framework and methodology of this research study. The study's empirical research findings are presented in the fourth section, and the conclusions and policy suggestions are presented in the last section.

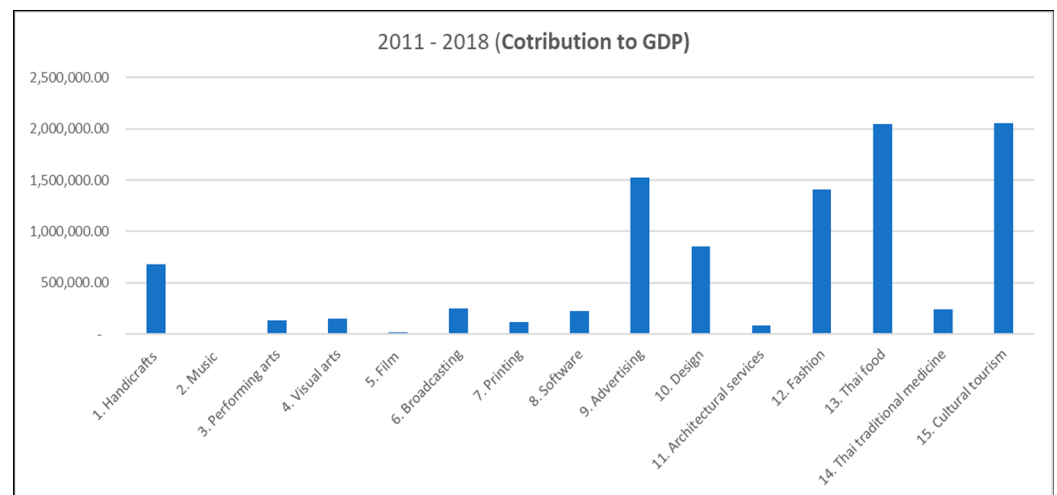


Figure 2. Top five creative economy sectors that have generated income for Thailand's economy between 2011–2018. Unit: A Million baht (USD 28,256.57).

2. Literature Review

Many research studies were discovered through an academic study of the creative economy, which played a significant role in driving the economies of various countries. For example, in 2018, Domench and Rausell-Köster studied the economic impact of the creative industry on the European Union (Boix-Domènech and Rausell-Köster 2018). This study found that the creative industry has a direct and indirect impact on the EU's economy. In 2019, Jin and his team studied the agglomeration economies in the creative industries of China (Tao et al. 2019). This research found that more agglomeration economies have an impact on the creative economy and can also contribute more income productivity to China's economy. In 2021, Palvo and Nikolaieva studied the impact of creative industries on Ukraine's economy (Iavorskyi and Nikolaieva 2021). This research study found that the multiplier of creative industries in Ukraine is equal to 1.9–2.2, which significantly impacts Ukraine's economy. In 2023, Koumoutsea evaluated the creative economy by applying the CVM to the Greek Cultural Heritage Festival, and they found that the festival has the potential to drive Greece's GDP in the future (Koumoutsea et al. 2023). According to research which examined the impact of the creative industries on local economic development in Ukraine, these sectors can generate employment in the country at a rate of 1.91% annually and contribute 3.47% to the national GDP (Pavliuk 2023). Furthermore, according to certain studies, the creative economy continues to show itself as more capable and fascinating for Thailand's economy. Danuporn and Sakornat, for instance, investigated Thailand's macroeconomic contribution and the creative economy (Ariyasajakorn and Sakornrat 2013). This study revealed that the Thai economy benefited greatly from the creative economy in many different ways. In 2020, Suprapa studied creative tourism management in Chiang Mai, and according to the results, there is a high potential for using creative tourism to drive Chiang Mai's economy in the future (Somnuxpong 2020). Lastly, the impact of the creative economy boost on the Thai economy was examined by Chokethaworn (Chokethaworn et al. 2023). This empirical study's findings indicate that fostering the creative economy is crucial to the long-term growth of Thailand's economy.

In many of the literature reviews, such as the study by Manioudis and Angelakis (2023), it was confirmed that creative economy development would be helped by the support of regional creativity, knowledge, and resources that contribute to an individual's entrepreneurial creativity in every creative economy sector. Matiza (2020) studied the role of creative industries in economic development. This study found that the development of the human factor is very significant in enhancing the creative economy in the long run. For example, fashion and music in Zimbabwe make up the creative economy sectors with high a potential and will develop successfully by empowering people in areas of values, skills, and knowledge based on creativity, to contribute to the development of the economy in the long run. Cong (2019) studied the significant creative economy sector that generated income for the GDP of Vietnam. This research study suggested that the creative service sectors of Vietnam have the potential to develop and need investment. These creative sectors include design, art, education, tourism, performing arts, fashion, handicrafts, culture, and foods.

According to previously stated literature reviews, the creative economy continues to have a noteworthy influence on long-term economic growth and development in several countries worldwide. Furthermore, the economy of the creative services industry needs attention and increased investment.

3. Conceptual Framework and Methodology

From Figure 3, the conceptual framework of this study will be started by employing a machine learning technique to extract the significant creative economy sector in Thailand for analysis by utilizing data from 2011 to 2018 (Source: The Office of the National Economic and Social Development Council of Thailand). This technique comes from both supervised learning algorithms (supervised learning classifier (K-NN)) and unsupervised learning algorithms (K-means clustering (K-means)) that attempt to find the most significant creative economy sector among the 15 creative sectors in Thailand's economy. Because this research article implements different algorithms used to analyze the same dataset, if the results obtained from these analyses are the same, then it will be possible to confirm that the results of these analyses are precise. The fifteen industries that make up Thailand's all-creative economy typically include handicrafts, music, visual arts, performing arts, film, broadcasting, printing, software, advertising, design, architectural services, fashion, Thai food, Thai traditional medicine, and cultural tourism.

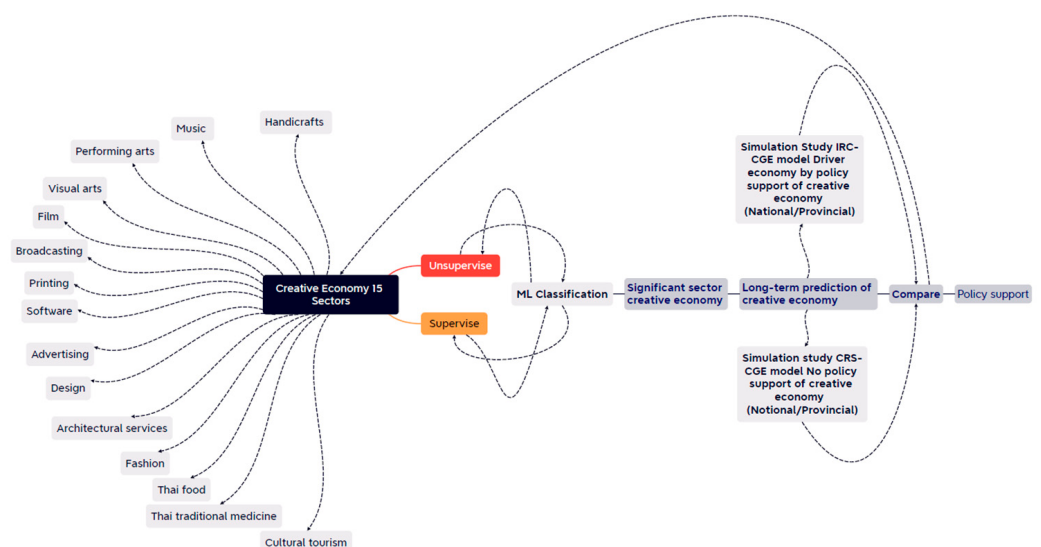


Figure 3. The conceptual framework and research methodology for examining the possible analytical effects of the main creative economy sectors on the long-term growth of Thailand's economy.

In addition, the GREY model (Deng 1982) was used to predict the long-term growth rate of major creative economy sectors and their contributions to the national and provincial GDPs, which are the initial values for a comparison study by the CGE model. The basic concept of calibration is to solve the unknown parameters in the long-run equilibrium for both the IRS-CGE model and the CRS-CGE model. Therefore, this research article utilizes the GREY prediction model to help deal with this situation in long-term general equilibrium computation.

Furthermore, in this research article, both the CRS-CGE model (constant return to scale) and the IRS-CGE model (increasing return to scale) were applied to study the potential of major sectors in the creative economy and their impact on the future of Thailand's economy. However, both the CRS-CGE model and IRS-CGE model were implemented to compute the general equilibrium of the economy under the standard microeconomic theory by allowing the price mechanism to drive the agents or economic sectors being analyzed. Therefore, when an economic policy is implemented and impacts the price mechanism, the policy maker can evaluate the effects of the policy on the long-term general equilibrium by using the CGE model.

According to the literature review, we can confirm that the creative economy or creative industry has a higher potential impact on the economy in terms of long-term productivity (Daubaraitė and Startiene 2017; Boix-Domènech and Rausell-Köster 2018; Manioudis and Angelakis 2023). Therefore, the scenario comparison study of this research assumes that the IRS-CGE model represents a future scenario where Thailand would significantly support the creative economy by launching a stimulus policy for long-term development. On the other hand, the CRS-CGE model represents a future scenario where Thailand would reduce support for the creative economy, with no additional projects to launch or support creative economy policy for long-term development. A comparison between both the IRS-CGE model and the CRS-CGE model will show whether long-term support of Thailand's creative economy would benefit the Thai economy at large.

3.1. Machine Learning for Clustering and Classification

In this research article, we would like to utilize machine learning for both clustering and classification of the important creative economy sectors in Thailand based on data collected during the period 2011–2018. Normally, machine learning has three algorithms: supervised learning, unsupervised learning, and reinforcement learning. However, this research article utilized only two algorithms to determine which creative economy sectors contributing the most income to the GDP of Thailand. The two algorithms utilized in this research article consist of the K-means clustering algorithm (unsupervised learning) and the K-nearest neighbors (K-NN) classification algorithm (supervised learning).

These algorithms are very well known and efficient for both clustering and classification analysis (Mittal et al. 2021; Octaviana 2021; Zhao et al. 2021; Zhao et al. 2022). One machine learning algorithm can learn from data without human supervision—also known as unsupervised learning—the other machine learning algorithm analyzes data with human supervision (using both data and human-justified analysis) and is called supervised learning.

3.1.1. The K-Means Clustering Algorithm (Unsupervised Learning)

The K-means clustering algorithm was first proposed by MacQueen (1967), and is a class of unsupervised learning. This class tries to let machine learning algorithms learn from data and analyzes them using a mathematical model without human supervision. The important point of K-means clustering algorithms is to compute the centroid value (see Equation (1)).

$$c^{(i)} := \underset{j}{\operatorname{argmin}} \|x^{(i)} - \mu_j\|^2 \quad (1)$$

where the variables are defined as follows:

$c^{(i)}$ = number of clusters which can be computed by the K-means clustering algorithm;

$x^{(i)}$ = the creative economy sectors of Thailand (15 creative economy sectors);
 μ_j = the initialize cluster centroids $\mu_1, \mu_2, \dots, \mu_k, \in \mathbb{R}^n$ which are the random points as the initial centroids.

The next cluster centroids can be computed by the mathematical formula displayed in Equation (2):

$$\mu_j := \frac{\sum_{i=1}^m 1\{c^{(i)} = j\} x^{(i)}}{\sum_{i=1}^m 1\{c^{(i)} = j\}} \quad (2)$$

The final step of the K-means clustering algorithm will be to cluster the creative economy sectors, which are the potential creative economy sector groups, to significantly contribute income to the GDP of Thailand in the future.

3.1.2. K-Nearest Neighbors (K-NN) Algorithm (Supervised Learning)

The K-Nearest Neighbors (K-NN) algorithm is a non-parametric supervised learning classifier that was initially introduced by [Fix and Hodges \(1951\)](#) (the original document was revised in 2020). Using algorithms based on training fed with labeled data sets is known as supervised learning. This research article also attempts to utilize the K-Nearest Neighbors (K-NN) algorithm for the classification of the creative economy sector, which is a significant group of the creative economy that has highly contributed income to the GDP of Thailand based on data between 2011–2018. The algorithm of the K-Nearest Neighbors (K-NN) can be described by Equation (3):

$$d(p, q)^2 = (q_1 - p_1)^2 + (q_2 - p_2)^2 \quad (3)$$

In Figure 4, it is the Euclidean distance of the K number of neighbors for the K-Nearest Neighbors (K-NN) algorithm. For example, it is used to compute the distance between point p and point q using the Euclidean distance formula (see Figure 4 and Equation (3)).

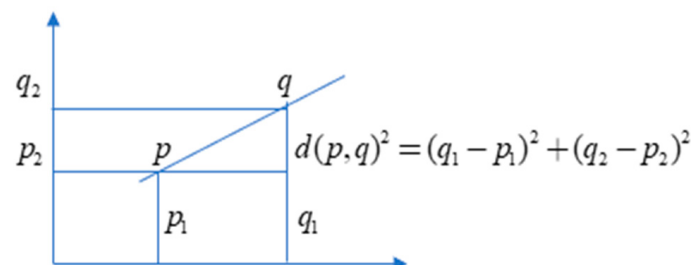


Figure 4. The Pythagorean theorem for the computation of Euclidean distance between point p and point q .

This algorithm attempts to classify the group by counting the number of data points under the condition of a K number of neighbors, which it is setting under human supervision. However, the results of these machine learning analyse, both the K-means clustering algorithm and the K-Nearest Neighbors (K-NN) algorithm, need to confirm that the outputs of the clustering and classification have the same direction.

3.2. GREY Model Prediction

For long-term prediction, this research article attempts to implement the GREY model to predict the long-term effects on Thailand's GDP from the income contributions of an important group of creative economies. This model was first proposed by [Deng \(1982\)](#); since then, many researchers have used it to predict time series data for long periods

(Li and Xie 2014; Song et al. 2020; Bilgil 2020; Xie 2022). The basic formula utilized by the GRAY model starts with Equation (4):

$$\frac{dx^{(1)}}{dt} + ax^{(1)} = b \quad (4)$$

Equation (4) represents the gray system theory on the first-order accumulation generated for the GREY model (1, 1). For this research article, the $x^{(0)}$ in Equation (6) stands for the growth rate of the income from the significant creative economy group sector, which is an important group of creative sectors that significantly contribute income to Thailand's GDP.

$$\hat{a} = |a, b|^T = (B^T B)^{-1} B^T Y \quad (5)$$

where $\hat{a}$ is the parameter that needs to be estimated for the GREY model (1, 1), while B and Y follow the formula below (see Equations (5)–(7)):

$$Y = \begin{bmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \vdots \\ x^{(0)}(n) \end{bmatrix} \quad (6)$$

$$B = \begin{bmatrix} -\frac{1}{2}[x^{(1)}(1) + x^{(1)}(2)] & 1 \\ -\frac{1}{2}[x^{(1)}(2) + x^{(1)}(3)] & 1 \\ \vdots & \vdots \\ -\frac{1}{2}[x^{(1)}(n) + x^{(1)}(n)] & 1 \end{bmatrix} \quad (7)$$

This model was implemented to predict the long-term income growth rate of the creative economy group that significantly contributes to Thailand's GDP. The income growth rate projection from the significantly creative economy group will be the initial value for scenario setting in the possible scenario comparison study for the Increasing Return to Scale Computable General Equilibrium Model (IRS-CGE model) and the Constant Return to Scale Computable General Equilibrium Model (CRS-CGE model) (see Figure 3).

3.3. IRS-CGE Model vs. Standard CRS-CGE Model

The Computable General Equilibrium (CGE) model is widely implemented in policy formulation in many countries under the assumption that price plays an important role in driving agents in an economy based on the theory of general equilibrium (Hosoe et al. 2010; Devarajan and Robinson 2013; Burfisher 2021). This research article also attempts to confirm that the creative economy should be supported and promoted more for the future of Thai economies, according to the CGE model simulation study perspective (Iavorskyi and Nikolaieva 2021; Chokethaworn et al. 2023).

In addition, a recent focus of many countries is that the creative economy or creative industry increases productivity, is more innovative, and adds more value to the demand and supply in their economies while being sustainable (Potts and Cunningham 2010; Iarmosh et al. 2021; Escaith 2022; Chokethaworn et al. 2023).

Therefore, the CGE model study-based concept of the IRS-CGE model was utilized to explore the sensitivity analysis of every sector in the economy of Thailand, and it was found that when there were effective policies put in place, the corresponding sectors responded positively. On the other hand, the CRS-CGE model still stands to explore the economic situation when the policymakers of Thailand give less promotion to the creative economy or less support to the creative economy to drive agents in the economy for long-term development (see Figure 3). From Figure 5, it is clearer how both the IRS-CGE model and the CRS-CGE model were utilized to examine the main creative economy sectors' possible analytical effects on Thailand's economy for long-term growth. Two comparative

models, the IRS-CGE model and the CRS-CGE model, were utilized to explore the effects of Thailand's economy with and without the stimulation of a future creative economy policy. In the two scenarios for this research study, the Social Accounting Matrix (SAM) (SAM table of Thailand (TDRI: Thailand Development Research Institute)) was used for initial data in this study. The basic mathematical equations to be used for the construction of both the IRS-CGE model and the CRS-CGE model can be written starting with Equation (8):

$$Y_j = b_j \prod_h F_{h,j}^{B_{h,j}} \quad \forall_j \quad (8)$$

$$F_{h,j} = \frac{B_{h,j} P_j^y}{P_h^f} Y_j \quad \forall_{h,j} \quad (9)$$

$$X_{i,j} = a x_{i,j} Z_j \quad \forall_{i,j} \quad (10)$$

$$Y_j = a y_j Z_j \quad \forall_j \quad (11)$$

$$P_j^z = a y_j P_j^y + \sum_i a x_{i,j} P_i^q \quad \forall_j \quad (12)$$

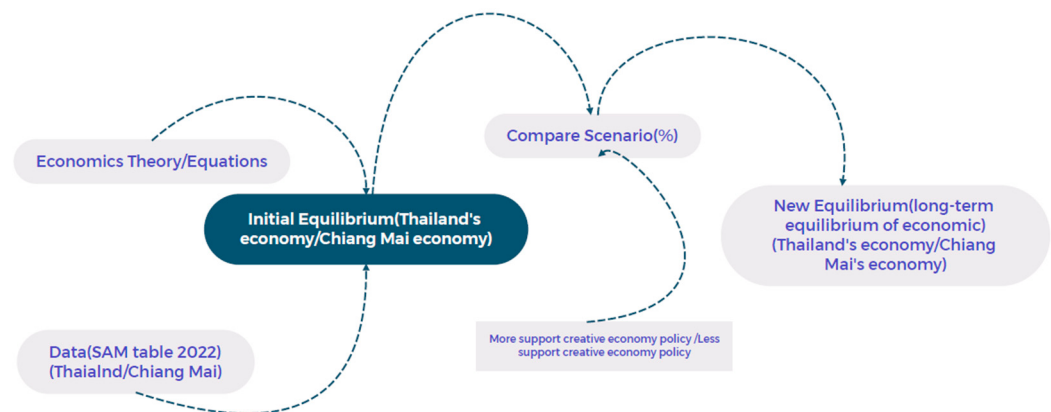


Figure 5. The schema of exploring the main creative economy sectors' possible analytical effects on Thailand's economy in long-term growth by both the IRS-CGE model and the CRS-CGE model.

Equations (8) and (9) represent the agents of the economic sectors as well as the domestic production sector in Thailand's economy. Furthermore, Y_j is the composite factor, $F_{h,j}$ is the input factor, $X_{i,j}$ is the intermediate input, Z_j is the output of goods, and P_j^z is the supply price of goods. Equation (12) through (16) would characterize the agents of the economic sector as the sector of government in the Thai economy.

$$T^d = \tau^d \sum_h p_h^f F F_h \quad (13)$$

$$T_j^z = \tau_j^z p_j^z Z_j \quad \forall_j \quad (14)$$

$$T_i^m = \tau_i^m p_i^m M_i \quad \forall_i \quad (15)$$

$$X_i^g = \frac{\mu_i}{p_i^q} (T^d + \sum_j T_j^z + \sum_j T_j^m - S^g) \quad \forall_i \quad (16)$$

From Equation (12) to (16), it is possible to explain the behavior of the agents in the economic sector of Thailand, which is explained by how the government will take action in this economy. T^d is the direct tax, T_j^z is the production tax, T_i^m is the import tariff, and X_i^g is government consumption.

$$X_i^v = \frac{\lambda_i}{p_i^q} (S^p + S^g + \varepsilon S^f) \quad \forall_i \quad (17)$$

$$S^p = ss^p \sum_h p_h^f FF_h \quad (18)$$

$$S^g = ss^g (T^d + \sum_j T_j^z + \sum_j T_j^m) \quad (19)$$

According to the economic stimulus agent sector for the CGE model of Thailand, Equation (17) to (19) represent the investments and savings from driving Thailand's economy. X_i^p , S^p , and S^g represent investment demand, private savings, and government savings, respectively. In the agent of the household behavior system for this study, it would be implemented the Equation (20) to understand the mechanism in Thailand's economy system underline the maximizing utility of household under budget constraint.

$$X_i^p = \frac{\alpha_i}{p_i^q} (\sum_j p_h^f FF_h - S^p - T^d) \quad \forall_i \quad (20)$$

X_i^p is the household consumption of the goods, or the household demand function for the goods of Thailand's economy. Furthermore, the agent used to describe Thailand's international economic sector will be able to describe detailed behavior using Equations (21)–(23).

$$p_i^e = \varepsilon p_i^{We} \quad \forall_i \quad (21)$$

$$p_i^m = \varepsilon p_i^{Wm} \quad \forall_i \quad (22)$$

$$\sum_i p_i^{We} E_i + S^f = \sum_i p_i^{Wm} M_i \quad (23)$$

where p_i^{We} is the export price, p_i^{Wm} is the import price, and Equation (23) is indicative of the balance of payment constraints for the Thai economy (E_i (Export), M_i (Import)). The Armington composite assumption was first proposed by Armington in 1969 (Armington 1969; Bajzik et al. 2020). This assumption is popular and powerful for explaining the international part of the CGE model.

The importance of the Armington composite assumption is that the total supply of an economy is equal to the aggregate of domestic products plus import products, which is changed by market price movements and technological movements (Sancho 2019) (See Equation (24) to (26)).

$$Q_i = \gamma_i (\delta m_i M_i^{\eta_i} + \delta d_i D_i^{\eta_i})^{\frac{1}{1-\eta_i}} \quad \forall_i \quad (24)$$

$$M_i = \left[\frac{\gamma_i^{\eta_i} \delta m_i p_i^q}{(1 + \tau_i^m) p_i^m} \right]^{\frac{1}{1-\eta_i}} Q_i \quad \forall_i \quad (25)$$

$$D_i = \left[\frac{\gamma_i^{\eta_i} \delta d_i p_i^q}{p_i^d} \right]^{\frac{1}{1-\eta_i}} Q_i \quad \forall_i \quad (26)$$

According to this assumption, the CGE model of Thailand is still using this assumption, which played a significant role in the description of the substitution effect between imports and domestic goods in this study. Q_i stands for Armington's composite goods, and D_i stands for domestic goods.

$$Z_i = \theta_i (\xi e_i E_i^{\Phi_i} + \xi d_i D_i^{\Phi_i})^{\frac{1}{1-\Phi_i}} \quad \forall_i \quad (27)$$

$$E_i = \left[\frac{\theta_i^{\Phi_i} \xi e_i (1 + \tau_i^z) p_i^z}{p_i^e} \right]^{\frac{1}{1-\Phi_i}} Z_i \quad \forall_i \quad (28)$$

$$D_i = \left[\frac{\theta_i^{\Phi_i} \xi d_i (1 + \tau_i^z) p_i^z}{p_i^d} \right]^{\frac{1}{1-\Phi_i}} Z_i \quad \forall_i \quad (29)$$

Equation (27)–(29) are carried out to describe the transformation between exports and domestic goods for the Thai economy (CET structure (see Hosoe et al. 2010)). In Equation (27), Z_i represents the total output of the goods for this country.

$$Q_i = X_i^p + X_i^s + X_i^v + \sum_j X_{i,j} \quad \forall_i \quad (30)$$

$$\sum_j F_{h,j} = FF_h \quad \forall h \quad (31)$$

For the market clearing (Walras's law), Equations (30) and (31) were used to explain the final output of the research, which was explained by the CGE model for the success of this study. By computing the general equilibrium for the Thai economy, we describe what happens when Thailand's economy is stimulated by creative economic policies, which lead to a new general equilibrium in the long run.

However, this research article attempts to utilize the IRS-CGE model (Increasing Return to Scale CGE model) (De Santis 2002; Hosoe et al. 2010; Waschik 2015) as a representative of the situation when the economy of Thailand has been affected by policies supporting the creative economy (Iarmosh et al. 2021; Che Arshad and Irijanto 2023). Additionally, the CRS-CGE model (constant return to scale) was applied in the examined Thai economy, which does not have policies supporting the creative economy or has some obstruction of the creative economy's development effect on the Thai economy in the future (Sullaida and Ahyar 2018; Baslandze 2021). Because the Thai economy has been stimulated more by the creative economy, especially by the group of creative economies that played a significant role among the fifteen creative economy sectors, it can produce more product at a constant marginal cost, but the fixed cost is unchanged (Hille 2001). From this perspective, the standard CGE model (CRS-CGE model) needs to be modified by adjusting some equation structures.

$$P_j^z = a y_j P_j^y + \sum_i a x_{i,j} P_i^q + \frac{FC_j}{Z_j} \quad \forall_j \quad (32)$$

$$T^d = \tau^d \left(\sum_h p_h^f FF_h + \sum_j FC_j \right) \quad (33)$$

$$S^p = ss^p \left(\sum_h p_h^f FF_h + \sum_j FC_j \right) \quad (34)$$

$$X_i^p = \frac{\alpha_i}{p_i^q} \left(\sum_j p_h^f FF_h + \sum_j FC_j - S^p - T^d \right) \quad \forall_i \quad (35)$$

Equation (32) to (35) were modified from many equations in the standard CGE model (CRS-CGE model); those that have been modified include: Equation (32), modified from Equation (12); Equation (33), modified from Equation (13); Equation (34), modified from Equation (18); and Equation (35), modified from Equation (20). Then, we put all of these equations in the IRS-CGE model (Increasing Return to Scale CGE model) (De Santis 2002; Hosoe et al. 2010; Waschik 2015) to represent the economic situation in which Thailand's economy is stimulated by the potential for a significant creative economy sector.

It can be concluded that many equations utilized in the IRS-CGE model have been modified from the standard CGE model (CRS-CGE model) by adding $FC_{CAP,j}^0 = (1 - \nu_j) \text{SAM}_{CAP,j}$ based on the concept that firms can produce more product at a constant marginal cost, but the fixed cost is unchanged (Hille 2001).

However, $FC_{CAP,j}^0 = (1 - v_j)SAM_{CAP,j}$ stands for the net use of the capital service in Thailand's Social Accounting Matrix as well.

$$P_j^z Z_j^0 = P_j^{y^0} Y_j^0 + \sum_i p_i^{q^0} X_{i,j}^0 + FC_j \quad \forall_j \quad (36)$$

Additionally, Equation (36) represents Thailand's GDP during the equilibrium state, or the long run between aggregate supply and demand, when the country's economy was influenced by policies supporting the creative economy.

4. Results

4.1. Machine Learning for Clustering and Classification Results

The 15 creative economy industries that have contributed significantly to the Thai economy between 2011 and 2018 are depicted in Figure 6. Handicrafts, music, visual arts, performing arts, film, radio, printing, software, advertising, design, architectural services, fashion, Thai food, traditional Thai medicine, and cultural tourism (Purple points in the left figure represent the 15 creative economy industries of Thailand).

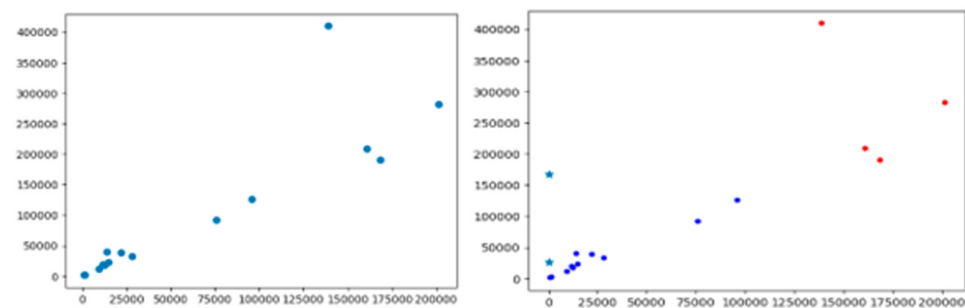


Figure 6. Presents the 15 creative economy sectors that generated income for Thailand's economy during the period of 2011–2018 (clustering into two groups by the K-means algorithm (Red points in the right figure represent Thailand's cultural tourism, Thai food, advertising, and fashion, respectively)).

The K-means clustering algorithm was employed to analyze the data, which consisted of the highest and lowest income contributed to Thailand's GDP from 2011 to 2018 (see Table 1) across all creative economy sectors. According to the approximated K-means clustering algorithm, Thailand's creative economies are divided into two groups. Among them is a group cluster with significant potential for income generation to support Thailand's economy. They are making a significant financial contribution to the economy of Thailand. The following four sectors make up most of the creative economic productivity of Thailand cultural tourism, fashion, advertising, and Thai food, in that order (see Figure 6 and Table 1).

Nonetheless, approval is required for the validation of both supervised learning (K-NN method) and unsupervised learning (K-means clustering algorithm). As a result, the K-means and K-NN algorithms must both verify that the classification and clustering outputs point in the same direction.

The results of the K-Nearest Neighbors (K-NN) algorithm's estimation are shown in Table 2 and Figure 7. Thailand's creative economy, which can be divided into two categories, contributed significantly to the country's GDP's income between 2011 and 2018, according to this methodology. The first group includes four creative economy industries that significantly contribute to Thailand's GDP in terms of revenue generation: Advertising, Fashion, Thai food, and Cultural tourism, in that order (see Table 2).

Table 1. The results of the estimation by the K-means clustering algorithm for two clusters of the creative economy.

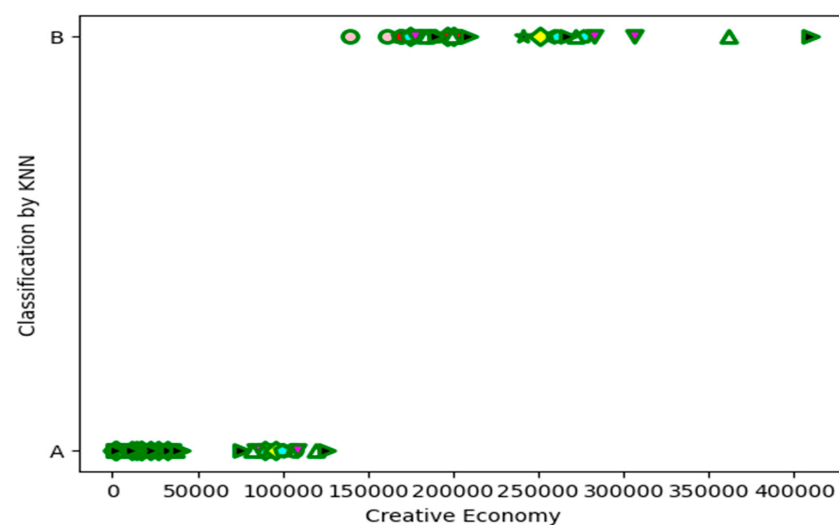
Creative Economy Sectors	Creative Types	Min (2011–2018)	Max (2011–2018)	K-Means Prediction
1. Handicrafts	A	76,000.00	91,765.00	0
2. Music	B	885.00	1478.00	0
3. Performing arts	C	11,846.00	19,537.00	0
4. Visual arts	D	14,937.00	23,091.00	0
5. Film	E	1606.00	2421.00	0
6. Broadcasting	F	28,176.00	32,939.00	0
7. Printing	G	12,499.00	17,258.00	0
8. Software	H	14,176.00	39,990.00	0
9. Advertising	I	161,006.00	208,803.00	1
10. Design	J	95,991.00	125,783.00	0
11. Architectural services	K	9395.00	11,355.00	0
12. Fashion	L	168,564.00	189,934.00	1
13. Thai food	M	201,542.00	282,212.00	1
14. Thai traditional medicine	N	22,135.00	38,906.00	0
15. Cultural tourism	O	138,833.00	409,891.00	1

Unit: Million baht (USD 28,256.57). Sources: Computed by authors.

Table 2. The results of the estimation by the K-NN algorithm for two group classifications of the creative economy.

Creative Economy Sectors	Creative Types	2011	2012	2013	2014	2015	2016	2017	2018	KNN-Prediction
1. Handicrafts	A	91,765	88,397	89,694	86,094	86,109	84,208	81,667	76,000	['A']
2. Music	B	885	1032	1128	1178	1246	1363	1388	1478	['A']
3. Performing arts	C	11,846	13,996	17,223	16,757	19,537	19,239	19,389	19,465	['A']
4. Visual arts	D	14,937	16,051	16,521	18,021	19,254	20,371	21,124	23,091	['A']
5. Film	E	1606	1829	1890	1875	2289	2380	2353	2421	['A']
6. Broadcasting	F	28,176	28,658	32,050	32,186	32,939	32,236	32,666	32,838	['A']
7. Printing	G	12,499	13,405	14,276	14,315	16,234	17,258	15,801	14,576	['A']
8. Software	H	14,176	16,542	22,212	29,060	31,459	32,715	36,539	39,990	['A']
9. Advertising	I	161,006	186,610	196,080	196,765	188,992	184,337	198,677	208,803	['B']
10. Design	J	106,485	99,166	95,991	100,691	99,462	108,035	119,350	125,783	['A']
11. Architectural services	K	9395	10,951	11,355	10,246	10,504	10,556	11,018	11,180	['A']
12. Fashion	L	169,620	168,564	174,859	169,480	174,003	177,311	183,826	189,934	['B']
13. Thai food	M	201,542	241,221	250,596	259,437	276,156	282,212	271,261	267,432	['B']
14. Thai traditional medicine	N	22,135	23,374	27,070	28,138	31,098	35,021	36,339	38,906	['A']
15. Cultural tourism	O	138,833	169,860	200,477	203,790	260,820	306,081	361,293	409,891	['B']

Sources: Computed by authors.

**Figure 7.** The 15 creative economy industries in Thailand that contribute income to the GDP of Thailand. (Two groups were classified by the KNN algorithm (Group B consists of 4 creative economy such as Thailand’s cultural tourism, Thai food, advertising, and fashion, respectively. Group A consists of 11 creative economy sectors such as handicrafts, music, visual arts, performing arts, film, radio, printing, software, design, architectural services, and traditional Thai medicine.).

However, the second group, which consists of eleven creative economy sectors, still contributes very little to Thailand's GDP. These sectors include handicrafts, music, visual arts, performing arts, film, broadcasting, printing, software, design, architectural services, and traditional Thai medicine.

Both the unsupervised learning (K-means clustering algorithm) and supervised learning (K-NN algorithm) indicate that the results of clustering and classification confirm that the major creative economy sectors are advertising, fashion, Thai food, and cultural tourism (see Table 2). They play a significant role in generating a high income for Thailand's GDP. Therefore, this research article uses these results to predict the long-term economic impact on the Thai economy using the GREY model.

4.2. Long-Term Prediction Result by GREY Model

The GREY model is used to predict the long-term economic effect of Thailand's economy based on the main creative economy sectors such as fashion, advertising, Thai food, and cultural tourism.

The expected impact of the key creative economy industries on Thailand's GDP from 2019 to 2025 is shown in Figure 8. According to the prediction results of the GREY model, these creative economy sectors (the four creative economy sectors) are expected to contribute to Thailand's GDP, which is projected to grow at an average annual rate of 6–7%. Therefore, it is necessary to thoroughly verify this growth rate using both the IRS-CGE model and the CRS-CGE model to understand the changes in each agent's structure when they participate in the Thai economy.

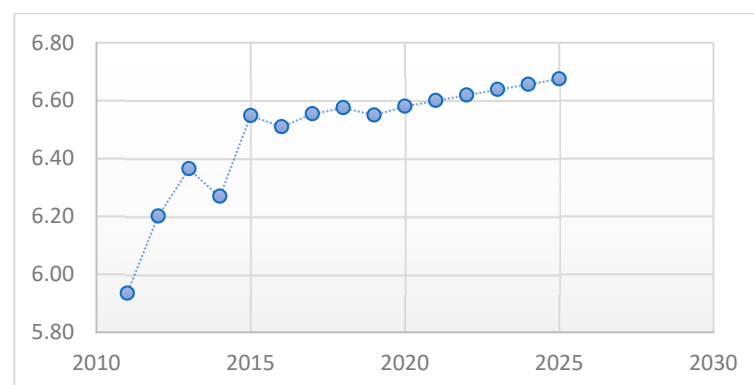


Figure 8. Prediction by the GREY model for the four creative economy sectors of Thailand with their income generated to the GDP of Thailand (2019–2025). (Y-axis: Growth rate of income generated to GDP, X-axis: Years).

4.3. The IRS-CGE Model and the Standard CRS-CGE Model Results

The influence of each agent on Thailand's economy under a highly supported or highly promoted creative economy strategy was investigated using the IRS-CGE model. However, the CRS-CGE model may still be used to investigate the economic conditions in which Thai policymakers provide less encouragement or support for the creative economy, which might act as a catalyst for long-term economic development in Thailand (see Figures 3 and 5). This study examines the long-term economic development in Thailand using the IRS-CGE and CRS-CGE models, with a focus on the national economy and provincial economies, for the purpose of evaluating creative economic policies. The province of Ching Mai was chosen for this study because it has more natural and cultural resources than other Thai provinces. Given this abundance, more attention should be given to the areas of fashion, advertising, Thai food, and cultural tourism (UNESCO 2017; Somnuxpong 2020).

4.3.1. National Economy (Thailand Economy)

Table 3 and Figure 9 display the results of the computation by comparing the IRS-CGE (the four major creative economy sectors contribute on average 7% to Thailand's

economy in the long term) and CRS-CGE models (the case where we ignore the stimulus to Thailand's economy by promoting creative economy policies) to evaluate the creative economy policies. The aims of the CGE model were developed primarily for policy analysis and evaluation. In this study, the IRS-CGE model confirms that most sectors of the Thai economy in the long run will gain sustainable, increasing income through the promotion of creative economy policies in advertising, fashion, Thai food, and cultural tourism.

Table 3. Computational results comparing the IRS-CGE and CRS-CGE models to evaluate the creative economy policies of Thailand.

Orders	Agents of Economic	Creative Economy Contribution		Creative Economy Contribution		Comparison	
		7 % (GDP) (Prediction)		0% (Prediction)		Multiplier	
		IRS-CGE Model (Thailand)		Standard CGE Model (CRS) (Thailand)		IRS-CGE vs. CRS-CGE	
		Products	Services	Products	Services	Products	Services
1	Household Consumption	80,232	46,072	5930	1715	13.53	26.86
2	Government Consumption	3779	17,737	536	1267	7.05	14.00
3	Investment Demand	199,650	166,410	279,920	117,520	0.71	1.42
4	Export	701	1,346,300	27,768	4492	0.03	299.74
5	Import	861,890	1,876,100	254,320	1,169,000	3.39	1.60
6	Domestic goods (Domestic goods demand function)	95,097	36,800	325,050	46,706	0.29	0.79
7	Gross Domestic Output	78,275	140,040	275,180	16,669	0.28	8.40
8	Production function (Labor/Capital)	30,637	87,687	112,230	10,842	0.27	8.09
Total		1,350,261	3,717,146	1,280,934	1,368,210	1.05	2.72
Household Utility Maximization			61,427.43		3277.74		18.74

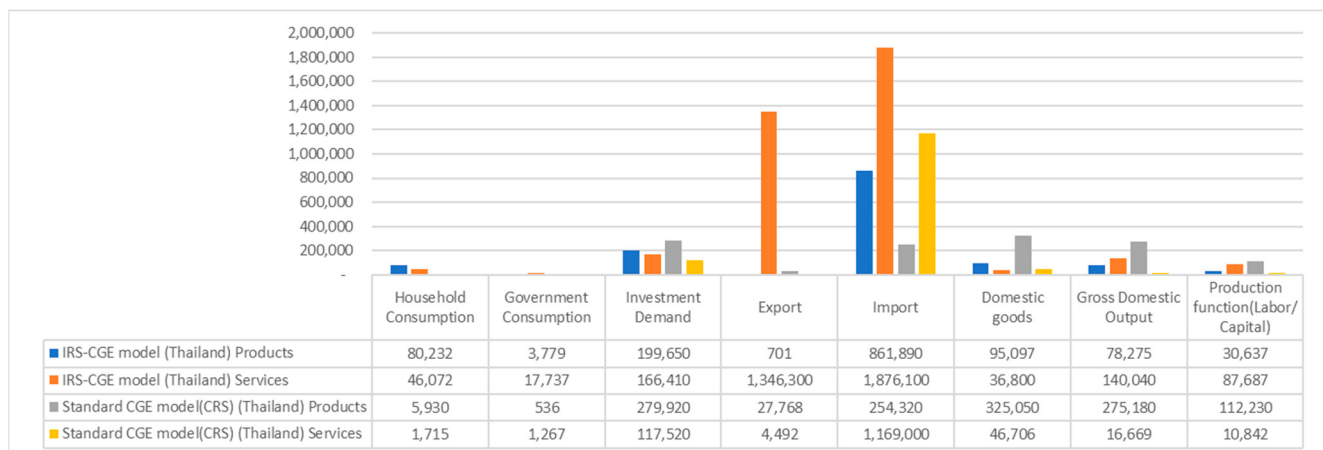


Figure 9. The result of the agent structure response to any creative economy policy of Thailand's economy was computed by both the IRS-CGE model and the CRS-CGE model of Thailand.

In Table 3, we see that all the computed agent sector results of the IRS-CGE model show an increase in both products and services in the long run when compared with the computed results from the CRS-CGE model.

Furthermore, the estimate of the household utility maximization results using the IRS-CGE model (both public and private sectors focus on supporting the creative economic policy in long-term economic development in Thailand) has shown an 18.74-fold increase in household satisfaction. This confirms that, in the long run, Thai households will experience an increase in happiness when creative economy policies are prioritized (see Table 3).

Moreover, all economic sectors in Thailand will benefit when both the public and private sectors focus on supporting the creative economic policy in long-term economic development. This is because the overall products and services in Thailand's economy have shown a 1.05-fold increase in products and a 2.72-fold increase in services, as shown in Table 3.

However, some sectors in the Thai economy do not benefit from the promotion of the creative economy policy because the CRS-CGE model (which ignores the development of a creative economy policy for long-term development in Thailand) suggests that sectors such as investment demand, export, domestic goods, gross domestic output, and production sectors have a greater benefit than the computed results from the IRS-CGE model (see Figure 9).

Thus, these sectors are depicted as having many multipliers in the IRS-CGE model, which is less than 1 when compared with the CRS-CGE model. It means that the creative economy policies of Thailand still encounter barriers to economic development in the long run; especially the domestic goods demand function of the Thai economy, which was confirmed by the IRS-CGE model to have multipliers that are less than 1 in both products and services. It is implied that although Thailand launched genuine creative economy policies in the past, the economy of Thailand is still declining, as the consumption products and services in the long-run are offset by inflation, which is continuously increasing. Therefore, the targeting inflation policy of the Bank of Thailand, which still attempts to control or target price stability by launching monetary policy, may be considered possible (BOT 2023). On the other hand, rather than impeding or discouraging this strategy for the Thai economy, the creative economy policy ultimately strengthens it. In particular, the IRS-CGE model's computation of the household utility maximization is greater than the CRS-CGE model's computation.

4.3.2. Provincial Economy (Chiang Mai Economy)

Over a decade ago, Chiang Mai's creative economy was propelled by policies and initiatives applied to the creative economy. The committee introduced several creative economy initiatives, as the Thai government has been pushing this province to become a creative province since 2010 by involving three sectors—including education, and private and government sectors.

In addition, on 31 October 2017, the United Nations Educational, Scientific, and Cultural Organization (UNESCO) recognized and honored Chiang Mai, the provincial capital, as a Creative City (crafts and folk art).

Table 4 and Figure 10 present the calculation results by contrasting the CRS-CGE and IRS-CGE models to assess the policies related to the creative economy in Chiang Mai. Overall, the IRS-CGE models suggest that in long-term equilibrium, Chiang Mai will gain economic growth as an achievable goal because this province is prioritizing planning to stimulate the economy by substantially supporting or promoting creative economy policies.

Table 4. Results of the computation comparing the IRS-CGE and CRS-CGE models to evaluate the creative economy policies of Chiang Mai.

Order	Agents of Economic (Chiang Mai Province)	Creative Economy Contribution		Creative Economy Contribution		Comparison	
		7% (GDP) (Prediction)		0% (GDP) (Prediction)		Multiple	
		IRS-CGE Model		CRS-CGE Model		IRS-CGE vs. CRS-CGE	
		Products	Services	Products	Services	Products	Services
1	Household Consumption	141,300	82,940	144,300	81,790	0.98	1.01
2	Government Consumption	6743	32,348	6885	31,896	0.98	1.01
3	Investment Demand	116,820	99,530	119,310	98,166	0.98	1.01
4	Export	620	2,834,200	827	2,778,700	0.75	1.02
5	Import	905,510	1,949,500	866,150	1,933,700	1.05	1.01
6	Domestic goods	91,636	54,429	103,490	53,674	0.89	1.01
7	Gross Domestic Output	75,419	292,500	85,195	286,810	0.89	1.02
8	Production function (Labor/Capital)	29,519	183,150	34,747	186,540	0.85	0.98
		1,367,567	5,528,596	1,360,904	5,451,276	1.005	1.01
	Household Utility Maximization		108,372		108,806		0.996

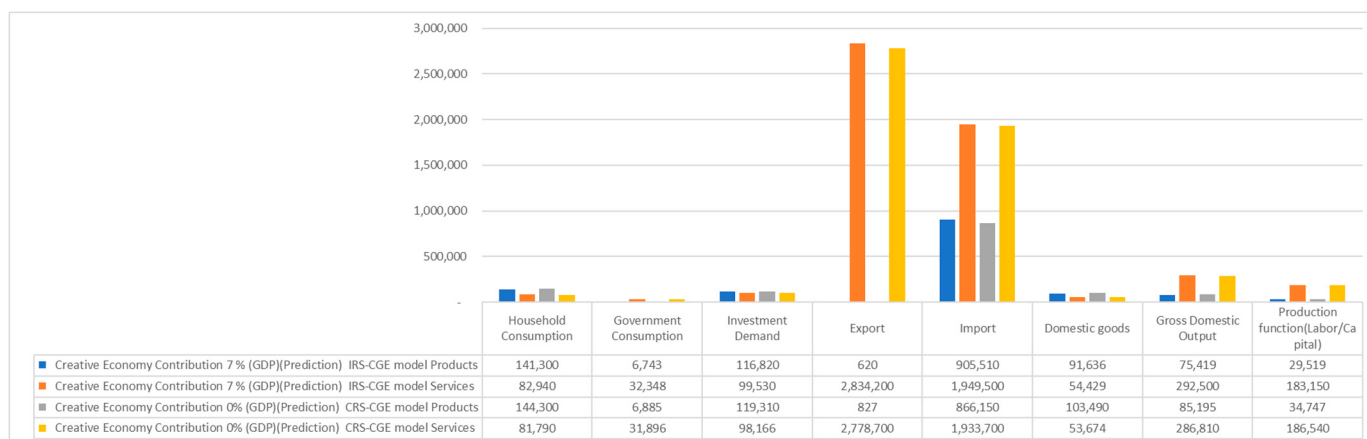


Figure 10. The results of the agent structure response to any creative economy policy for Thailand's economy were computed by both the IRS-CGE model and the CRS-CGE model of Chiang Mai.

Because the IRS-CGE models show that when Chiang Mai's economy is continuously supported or promoted by creative economy policies, the Chiang Mai economy experiences an overall expansion of more than a 1-fold increase in both products and services. In Table 4, it can be seen that all economic sectors in Chiang Mai will benefit when both the public and private sectors focus on supporting the creative economic policy in long-term economic development. This is because the overall products and services in Chiang Mai's economy have shown a 1.005-fold increase in products and also a 1.01-fold increase in services, as shown in Table 4 and Figure 10.

Nevertheless, the products in Chiang Mai will decrease in the long run when comparing the IRS-CGE models and the CRS-CGE model for assessing the creative economy policy in the province. Hence, the household consumption sector, government consumption sector, investment demand sector, export sector, domestic goods sector, gross domestic output sector, and production function sector will all undergo a less-than 1-fold decrease, except for the import sector. This is a significant issue for the province; over time, Chiang Mai's creative economy will mainly be driven by the service sector. Consequently, the province may need to import products from outside of the Chiang Mai province or from other provinces. Given that Chiang Mai's social character is characterized by farmers who grow rice and garden fruit (Somnuxpong 2020), some of these individuals may not participate in the creative economy business sector. As a result, these people or other locals with similar characteristics may experience long-term negative effects from the implementation of creative economy policies. Moreover, the computation of household utility maximization in the Chiang Mai province, when comparing the IRS-CGE model and the CRS-CGE model, found that it is less than 1. This implies that overall, people in Chiang Mai still experience low household utility maximization in the long term if the province attempts to stimulate the economy through creative economy promotion or by supporting creative economy policies with an unbalanced economic system.

5. Conclusions and Policy Recommendation

The United Nations has promoted and supported the UNCTAD Creative Economy Programme since 2004 (UNCTAD 2023) to help countries around the world understand how to promote economic development through creativity in industries for their countries. Fortunately, the Thai government recognizes that the creative economy has the ability to propel Thailand's economy from a middle-income to a high-income nation. According to the issues above, this research study aims to determine whether Thailand's economy will eventually reach its goal of becoming a high-income country through creative economy-driven growth in the long run. The conclusion of this study confirmed that Thailand's economy would achieve its goal of becoming a high-income country through creative economy-driven growth in the long run if it continues to promote and support creative

economies. The policy to promote and support creativity must be emphasized early on and prioritized; especially for the four creative sectors such as fashion, advertising, Thai food, and cultural tourism, to provide revenue for Thailand's national economy and Chiang Mai province's economy later on.

This conclusion of the empirical research results is also relevant to the conclusion of research results from the (NESDB 2008), which still confirmed that four creative economy sectors have played a significant role in driving the Thai economy.

The conclusion is similar to the perspective of the National Economic and Social Development Board (NESDB 2008)—that four creative economy sectors will be very powerful in driving the economy of Thailand in the future. Each of these sectors has a unique characteristic and opportunity, making them potential drivers and stimulators of Thailand's economy.

For example, cultural tourism has the potential to be a great creative economy sector because some cultural heritage tourism areas in Thailand have been promoted by the brand of UNESCO's cultural heritage. Additionally, the Thai food sector has been promoted by the "5 Fs project (food, film, fashion, fighting (Thai martial arts), and Thai traditional festivals)", and has been supported by the Thai government since 2020. Additionally, the Thai government established the Queen Sirikit Institute of Sericulture in 2005 to develop high standards of fashion based on modern Thai cultural concepts. This can serve as advertising for the premium fashion brands of Thailand, making it well known worldwide.

Moreover, this research result seems to be similar to Ukraine's economy, which was driven by continuous investment in the creative economy sector in both the national and local economies (Skavronska 2017; Iavorskyi and Nikolaieva 2021; Pavliuk 2023).

The policy recommendation from this research study points out that the Thai economy needs to be driven by creative activity, and it must keep doing so continually (Prayudi and Probosari 2022). These policies can be promoted both in the primary education system and in the higher education system.

In terms of the four important creative sectors, which consist of fashion, advertising, Thai food, and cultural tourism, there is a need for promotion and supportive policies. For example, Thailand's fashion, Thai food, and cultural tourism should be promoted using the unique Thailand soft power, like Japan and South Korea. Japan started the Cool Japan concept in 1980 to promote its creative economy, with a focus on building the nation's brand to be well known worldwide. In the advertising creative economy sector, Thailand's creative policy should learn from South Korea's policy, which aims to advertise the country's image by being brand ambassadors of Southeast Asia. Thailand must develop its creative economy, particularly in the advertising sector, by becoming the brand ambassadors of Southeast Asia through collaborative projects with other countries in this region.

In addition, both the public sector and private sector of Thailand must try to open an area for key persons of the creator grooming community to work together and help Thailand achieve sustainable economic development through a creative economy-driven approach. Furthermore, the specific importance of the creative economy policy of Thailand must be based on the optimal ecosystem management policy in both the national economy and the local economy as well (Xepapadeas 2009; Tao et al. 2019).

According to the main policy recommendation of this research article, it still emphasizes that the creative economy-driven approach must be addressed first. Estrada (2022) suggested that two theoretical approaches were popularly applied for the development of the creative economy in many countries' economies around the world. Firstly, there is the creative-cultural classes approach, and secondly, there is the media and culture-in-society approach. In terms of policy support, the creative-cultural classes approach in Thailand for fashion, advertising, Thai food, and cultural tourism needs to provide more training and education for all workers in these four significant creative sectors in Thailand's economy.

For example, the advertising creative sector can create more than 50,000 jobs and contribute more than 10 billion baht in 2021 (USD 285,802,067.78) to Thailand's economy.

These workers must receive more training and education to enhance their skills through the concept of Creator Education. Similarly, the fashion, Thai food, and cultural tourism sectors need to develop or enhance the skills of their workers to work effectively in these significant creative sectors.

Finally, the policy recommendation of this research is based on the media and culture-in-society approach. The key to this policy depends on changing the revolution in communication technologies (Levickaitė 2011). Therefore, stakeholders in the creative economy of Thailand must consider this key priority. For example, fashion, advertising, Thai food, and cultural tourism are promoted through the Thai branding image, which is supported by the revolution in communication technologies. For instance, policy makers must facilitate a digital platform to support local and global demand, making it easy to access tangible Thai fashion, Thai food, and cultural tourism.

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