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Research Article

The Dynamic Effect of Unemployment Rate and Crime Rate on Suicide Rate under Economic Growth Rate

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In this study, the panel smooth transition regression model was used for an empirical survey to investigate the dynamic effect of unemployment rate and crime rate on suicide rate under economic growth rate. The research period was from 2000 to 2019. Statistical results indicated that unemployment rate and crime rate had dynamic effects on suicide rate and that nonlinear relationships existed among them. In addition, depending on the fluctuation of dynamic value, the rise or fall of suicide rate had an asymmetrical influence on the value of unemployment rate and crime rate. Finally, when the rate of change of economic growth rate was larger than the dynamic value, the unemployment rate and crime rate had an aggressive influence on suicide rate.

1. Introduction

Taiwan was a transport point for economy and trade and was a base in the war period, giving it a very important strategic position. Given its past "past economic miracle" [1], Taiwanese people had sufficient capital to travel around the world, with increased flow in cash, materials, and people. However, today, such lavish scenes no longer occur.

From 1951 to 1990, Taiwan had frequent trade with foreign countries, and for a continuous 40 years, its average economic growth rate had reached 9%, which was the highest worldwide [2]. In 1985, the exchange rate between the New Taiwan dollar and US dollar rose from 40.6 to 24.52 in 1992 and slowed down from then. This attracted a rush of hot money into the stock market to profit from the exchange rate difference. From 1985 to 1990, a period of only five years, this rush led to a 20-fold rise in stock price, and real estate had a 10-fold increase. In this period, the stock market was so appealing, becoming a site of high trading volume where people could easily earn regardless of the stocks bought [3]. According to statistics from the Directorate-General of Budget, Accounting and Statistics of Executive Yuan [4], the economic growth rate rose quickly from 4.81% in 1985 to 12.75% in 1987. This was so unprecedented that threefold growth was generated in only two years.

Taiwan's stock market had reached a record high in February 1990, at 12,682 points. However, such periods usually do not last long. When most people were still preoccupied with the pursuit of wealth, unexpected and sudden bad news arrived. In a very short period of less than one year, the stock market collapsed to 2,485 points, and people with many stocks were heavily affected [5]. According to data from National Statistics, Republic of China [6], from 1995 to 1996, a period of only one year, the unemployment rate in Taiwan rose abruptly from 1.79% to 2.6%, also affected by the Asian financial crisis. The

unemployment rate continued to rise to 2.99% by 2000. From the data of the Directorate-General of Budget, Accounting and Statistics of Executive Yuan [4], the economic growth rate plummeted from 6.31% in 2000 to −1.4% in 2001.

According to statistics on the website of the National Police Agency, Ministry of the Interior of the Republic of China (2020), Police Agency [7], the occurrence of criminal cases rose from 386,241 cases in 1999 to 555,109 cases in 2005, clearly showing that criminal cases increased year by year. In addition, the process of economic growth was always accompanied by positive and negative influences. In regular public life, many trivial things were added. In such an unstable social environment, people were exerting effort to maintain certain living standards. According to the statistical data of the legal entity Association for Suicide Prevention (2019), from 1997 to 2009, the suicidal behaviour of intentional self-harm had entered the top 10 causes of death in Taiwan. Especially in the period from 1999 to 2005, the crude death rate from suicide rose from 10.4 persons to 18.8 persons per 100,000 population. The reemergence of the suicide death peak in Taiwan was in 2006, and the crude suicide death rate was 19.3 persons per 100,000 population.

The World Health Organization (WHO) pointed out that, each year, about 800,000 people died by suicide, equivalent to one person dying every 40 seconds. The statistics also showed that, in 2016, the global standardised suicide death rate was 10.5 persons per 100,000 population [8]. Suicide has become a topic that cannot be neglected, and the global trend of suicide has also shocked people around the world. Suicide rate, for Taiwan and other countries, has become a very important public health issue, and its influence on society has been tremendous. As previous researchers noted, "The trend of suicide rate showed a significant correlation to social-economic factors, and when unemployment rate and poverty rate rose, suicide rate rose accordingly too" [9].

The economy is one competition index that represents the economic cycle of a country, and its fluctuation usually accompanies a country's economy. When a country's economy is in recession, it will accordingly affect the number of personnel that enterprises can hire and the salary that enterprises can pay. It will also lead to an increase in the unemployment rate. Therefore, if people cannot achieve minimal and basic requirements or satisfy psychological requirement levels as mentioned by the American psychologist [10], then people will naturally have other ideas for further self-harming behaviour, such as suicide. In addition, other scholars also proposed similar viewpoints, such as the rise in unemployment rate leading to a rise in suicide rate and the strong relationship between the two [11].

Taiwan has gone through several paradigm shifts. The rise or fall of average of the economic growth rate of Taiwan affected the fluctuation of average unemployment, crime, and suicide rates, as shown in Figure 1.

To sum up these results, the economic change in 2001–2009 was clear. In this period, historical economic fluctuations came one after another, the average economic growth rate dropped to its record low of 3.6%, and average

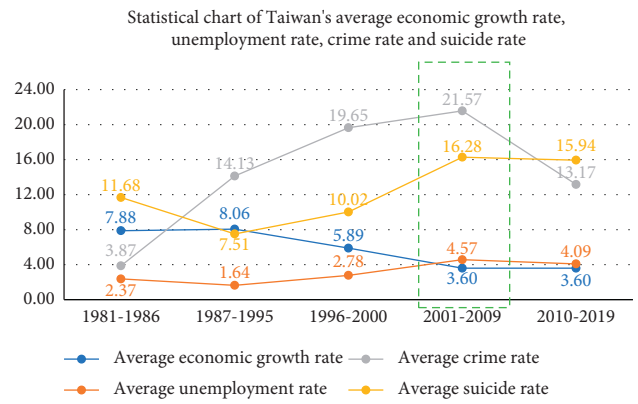

Figure 1: Statistical chart between Taiwan's average economic growth rate, unemployment rate, crime rate, and suicide rate from 1981 to 2019. Data source: National Statistics, R.O.C. (Taiwan), National Police Agency, Ministry of Interior, R.O.C. (Taiwan).

unemployment rate continuously rose to 4.57%. The average crime rate (21.57%) also showed a continuous rise. Moreover, the average suicide rate was as high as 16.28 persons per 100,000 population. Such a shocking statistical result reflected the poor social-economic situation. Therefore, the recession of the economic factor, in addition to leading to the rise in unemployment and crime rates, will also directly affect the rise of average suicide rate. Under the economic growth situation in Taiwan, the main objective of this study was to investigate the nonlinear relationship of unemployment and crime rates to suicide rate.

2. Literature Review

2.1. Correlation among Economic Growth, Unemployment, and Suicide Rates. Unemployment is a crucial economic factor in explaining suicides. Nordt, Warnke, Seifritz, and Kawohl [12] estimated that suicide relates to unemployment in around 20% of all cases. Platt and Hawton [13] studied Europe and North America using empirical evidence to examine the relationship between suicidal behaviour and the labour market that depended on a system and structure. The research period began in 1984, and they found that unemployed individuals are approximately three times more likely to commit suicide than those who are employed. Chang, Stuckler, and Gunnell [14] used trend analysis to investigate European and American countries under the impact of the 2008 global economic crisis on global inclinations towards suicide. They found that, after the crisis, suicide rates increased. They also found that job loss among young people is closely related to suicide rates.

Muscatelli and Tirelli [15] empirically studied the relationship between unemployment and economic growth for countries of the Organization for Economic Cooperation and Development (OECD): Australia, Austria, Belgium, Canada, Chile, Columbia, Czech Republic, Denmark, Republic of Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, Slovenia, Spain,

Sweden, Switzerland, Turkey, England, and USA. The research period was from 1955 to 1990 and the structural vector autoregression (VAR) model was used. They found a negative relationship between economic growth and unemployment. Huikari and Korhonen [16] used the fixed effect panel regression method, interaction model, and dynamic regression model to study the relationship between unemployment and economic crises under suicide mortality for 21 OECD countries from 1960 to 2011. They found that economic or unemployment rates tended to lead to the rise in suicide head count, and a positive correlation existed between unemployment and suicide head count. Soylu, Çakmak, and Okur [17] studied the relationship between economic growth and unemployment rate in countries in Eastern Europe (East Europe countries: Belarus, Bulgaria, Czech Republic, Romania, Poland, Ukraine, Hungary, and Slovenia) using panel unit root, pooled panel ordinary least squares (OLS), and panel Johansen cointegration test. The research period was 1992–2014. They found that unemployment rate was aggressively affected by economic growth and a negative relationship existed between the two.

Suicide is among the severe health issues that have been confirmed to be associated with economic conditions. Lin [18] employed two panel data sets for Taiwan and other Asian countries to examine the relationship between the unemployment rate and the suicide death rate by using fixed-effects models. They found that the suicide death rate moves countercyclically with the unemployment rate. In other words, the higher the income, the lower the suicide death rate. They also found a clear relationship existed among economic growth, unemployment rate, and suicide rate. Chang [19] used a VAR model, assisted by variance decomposition and impulse response function, to investigate the relationship between economic growth and unemployment rate in Taiwan. They used time series data for a period spanning the first season of 1981 to the third season of 2003. Empirical results indicated that economic growth will negatively affect unemployment rate and that a long-term balanced relationship existed between the two. Park et al. [20] studied the influence of economic growth and unemployment rate on suicide rate in Korea using the first-order autoregressive regression model in time series. For the 1983–2003 period, the scope of suicide rate, unemployment rate, and GDP in Korea was simulated and tested. They found a negative correlation between GDP and suicide rate and a positive correlation between unemployment rate and suicide rate.

2.2. Correlation among Economic Growth, Crime, and Suicide Rates. Cameron [21], studying the relationship between murder and suicide in England and Wales from 1900 to 1949 using a simple econometric model, did not find a relationship between the two.

Habibullah and Baharom [22] studied the influence of economic status on crime activity in Malaysia in 1973–2003. Autoregressive distributed lag bounds testing was used as a research method, and dynamic OLS was used to test the robustness of the results. They found a long-term relationship between crime activities such as murder, robbery with guns and theft, and economic status. Economic status was the cause, and crime rate was the effect. Under long-term effects, economic growth showed a negative influence on gun robbery.

However, in the USA, compared with other countries, violent death was still the most important public health problem. Richardson and Hemenway [23] compared the crime and suicide rates for the USA and 23 high-income OECD countries. They conducted cross-sectional analysis according to death rate data provided by WHO in 2003. They found that the USA's crime rate was 6.9 times higher than those of other countries.

Kathena and Sheefeni [24] studied the relationship between economic growth and crime rate in Namibia. The research period was from first quarter of 2000 to fourth quarter of 2015, and time series data were adopted. Under the VAR framework, they used unit root, Johansen cointegration, and Granger-causality methods. They found that the rise in crime rate had affected the drop in economic growth.

Machado et al. [25] studied the relationship between homicide rate and suicide rate for seven years from 2008 to 2014 for municipalities in Brazil. They conducted a longitudinal ecological study using annual death rate data from 5,507 cities using a multivariable negative binomial regression model. They found a positive correlation between suicide and homicide rates.

In summary, a mutually interacting and close relationship exists among economic growth, unemployment, crime, and suicide rates.

2.3. Nonlinear Model. Granger and Teräsvirta [26] pointed out that because most macroeconomic variables tend to be nonlinear, if heterogeneity exists between variables in the empirical modelling process, specification errors will appear in the estimation process using traditional linear models, leading to biased estimates. To solve this problem and obtain more accurate empirical conclusions, in recent years, more and more scholars have adopted nonlinear empirical models when the model variables have heterogeneous structures. The most common types and characteristics of nonlinear models in the empirical literature include the threshold autoregression model [27], which constitutes a nonlinear state switching model. However, capturing the true state of transition in the model in empirical research is difficult because the transition process of the model is aggressive and discrete. Therefore, the model type often cannot fully and accurately capture the transition process of low-frequency data. The smooth transition autoregression (STAR) model was proposed by [28]. It consists of two nonlinear autoregressors connected by a transition function that allows the variable to move between two different states, ensuring that a smooth transition process consisting of lagging transition variables is determined. However, this model is not suitable for models with cross-sectional data structures.

The main feature of the panel threshold regression (PTR) model proposed by Hansen [29] is the use of a time-varying

threshold variable to divide the panel data into several different intervals, so that when the observation data approaches the transition threshold, jumps occur. However, this phenomenon is rare in the real world. After changing the jump transition in this PTR model to a smooth transition, González et al. [30] proposed the panel smooth transition regression (PSTR) model concept and added a transition velocity parameter to their model. This transition speed parameter is used to describe the smooth transition phenomenon of the model around the threshold, ensuring that the transition is not a simple jump. Transition variable thresholds were also estimated using quantitative methods rather than artificially specified ones. This objective estimation method avoids biases in the estimated model extremes due to subjective preconceptions of the researchers. Given the characteristics and advantages of the PSTR model, more and more scholars have recently adopted such models in their research [31–36].

Therefore, this research uses a PSTR model to assess the dynamic effect of unemployment rate and crime rate on suicide rate under economic growth rate. The model can assess the effect of data that is nonlinear and has a cross-sectional structure on suicide rate, while also effectively presenting the dynamic smooth transition process of suicide rate. Importantly, these features not only avoid biased results that can occur when using traditional linear models but also allow for accurate estimates of changes in suicide rates due to the economic effects of crime and unemployment.

3. Research Method

3.1. Research Variable. The main objective of this study was to investigate, under Taiwan's economic growth rate, the nonlinear influence of unemployment rate and crime rate on suicide rate. Four variables were used for this study. The transformation variable was economic growth rate, and the data source was the Directorate-General of Budget, Accounting and Statistics, Executive Yuan. The independent variables are the crime rate and unemployment rate. The data source for the crime rate was the website of the National Police Agency, Ministry of the Interior, Republic of China. In addition, the data source for the unemployment rate was acquired from National Statistics, Republic of China (Taiwan), except for Kinmen and Liangjiang counties. The unemployment rate of Kinmen county was acquired from the chief accounting office of the county government. For the unemployment rate of Liangjiang county, data from 2000 to 2012 was acquired from the county annals and data from 2013 to 2019 was acquired from the Liangjiang county government. The dependent variable was suicide rate, and the data source was the statistics office of the Ministry of Health and Welfare. Annual data from 2000 to 2019 were used.

To cope with the need of empirical model analysis, all the variables were changed into the form of rate of change as in

$$V_{r,t} = \frac{V_t - V_{t-1}}{V_{t-1}}. \tag{1}$$

Formula (1) represents the rate of change of economic growth rate, unemployment rate, crime rate, and suicide rate. $V_{r,t}$ represents the rate of change of economic growth rate, unemployment rate, crime rate, and suicide rate of t term. V_t represents economic growth rate, unemployment rate, crime rate, and suicide rate of t term. V_{t-1} represents economic growth rate, unemployment rate, crime rate, and suicide rate of $t-1$ term.

The research variable name, code, and data source of each research variable were summarised in Table 1.

3.2. Division of Northern, Central, and Southern Areas in Taiwan. The jurisdiction scope of the Supreme Administrative Court is divided into affairs and territorial jurisdictions. In this study, territorial jurisdiction was used [37], which is shown in Table 2. It can be mainly divided into three parts: northern, central, and southern. Therefore, in this study, according to the scope of territory jurisdiction, the data of economic growth, unemployment, crime, and suicide rates for this study were divided into northern, central, and southern areas according to 22 county and city areas of Taiwan. This division is shown in Table 2.

3.3. Research Model

3.3.1. Linear Model. To evaluate the dynamic effect of unemployment rate and crime rate on suicide rate under Taiwan's economic growth rate, panel data were first used to analyse the influence of unemployment rate and crime rate on suicide rate. The empirical linear model is shown in

$$S_{rit} = \alpha_0 + \theta_1 U_r + \theta_2 C_r + \varepsilon_{it}, \tag{2}$$

where $i = 1, 2, \ldots, N$ represents the suicide rate of cross section, and $t = 1, 2, \ldots, T$ represented time. S_r represents the rate of change of Taiwan's suicide rate, α_0 is constant, U_r represents the rate of change of the independent variable unemployment rate, and C_r represents the rate of change of the independent variable crime rate. θ_1 and θ_2 are, respectively, coefficients of the independent variables unemployment rate and crime rate and ε_{it} was error item i of t term.

3.3.2. Panel Smooth Transition Regression Model. The first step in using PSTR was to inspect if heterogeneity existed in the panel data. If this was shown by the test result, then this model was a nonlinear panel model. PSTR also includes two extreme regimes, namely, the linear and nonlinear homogeneity panel models, and a single transfer function. According to Teräsvirta [38], the latter was frequently used in single-formula STR or single-variable (STAR) models. The model was written as

$$S_{rit} = \alpha_i + \theta_0 X_{it} + \theta_1 X_{it} G(q_{it}; \gamma, c) + \mu_{it}, \tag{3}$$

where $i = 1, 2, \ldots, N$ represents number of individuals, $t = 1, 2, \ldots, T$ represents time, and S_{rit} represents the rate of change of the dependent variable suicide rate. X_{it} represents the vector of the exogenous independent

Table 1: Classification, name, code, and data source of research variables.

Classification	Name of variable	Code	Data source
Transfer variable	Rate of change of economic growth rate	Er	Directorate-General of Budget, Accounting and Statistics, Executive Yuan
Independent variable	Rate of change of unemployment rate	Ur	National Statistics, R.O.C.(Taiwan), chief accounting office of Kinmen county government, Liangjiang county annals, and Liangjiang county government
	Rate of change of crime rate	Cr	Website of National Police Agency of Ministry of Interior of Republic of China
Dependent variable	Rate of change of suicide rate	Sr	Accounting Office of Ministry of Health and Welfare

Note. (1) In this study, suicide crude death rate was adopted, that is (death count/mid-year population) × 100,000. (2) The research period was from 2000 to 2019.

Table 2: Territorial division of northern, central, and southern areas in Taiwan.

Territorial division	County and city type
Northern area	Taipei city, New Taipei city, Taoyuan city, Hsinchu county, Hsinchu city, Keelung city, Yilan county, Hualien county, Kinmen county, Liangjiang county
Central area	Miaoli county, Taichung city, Changhua county, Nantou county, Yunlin county
Southern area	Chiayi county, Chiayi city, Tainan city, Kaohsiung city, Pingtung county, Taitung county, Penghu county

Data source: Supreme Administrative Court.

variable, in other words, $X_i = (U_r, C_r)$. $G(q_{it}; \gamma, c)$ represents a transfer function, where q_{it} represents the transformation variable, with a value from 0 to 1. γ and c represent transformation speed and transformation dynamic value, respectively. α_i is the constant item, which represented the fixed effect of individual. μ_{it} was error item i of t term.

According to González et al. [30], the transfer function was set up as

$$G(q_{it}; \gamma, c) = \left(1 + exp\left(-\gamma = \prod_{j=1}^{m}\left(q_{it} - c_j\right)\right)\right)^{-1}, \quad (4)$$

where $\gamma > 0$, and $C_1 \leq C_2 \leq \cdots \leq C_m$. $c = (c_1, \cdots, c_m)\prime$ represents the location parameter of m space vectors. Regardless of $m = 1$ or $m = 2$, γ values will all affect the slope of $G(q_{it}; \gamma, c)$ function. When $m = 1$ and $\gamma \longrightarrow \infty$, the figure will become more abrupt, and PSTR will converge the PTR. By contrast, when $\gamma \longrightarrow 0$, because $G(q_{it}; \gamma, c)$ function was in the range from 0 to 1 and approaches linear function, PSTR was estimated to become a linear panel model with fixed effect. González et al. [30] thought that, from an empirical perspective point, the situation of the linear model is due to status transformation. Therefore, the PSTR model was as shown in

$$S_{rit} = \alpha_i + \theta_0 X_{it} + \sum_{j=1}^{\gamma} \theta_j X_{it} G_j\left(q_{it}; \gamma_j, c_j\right) + \mu_{it}, \quad (5)$$

where $j = 1, 2, \ldots, r$ represents the quantity of transfer function and $r + 1$ represented the quantity of status.

3.3.3. Linearity and No-Remaining Nonlinearity Tests. According to the study of Wu et al. [39], the first-order Taylor expansion of common formula (5) in this paper, through the use of transfer function and at $\gamma = 0$, can replace transfer function $G(q_{it-d}; r_j, c_j)$. Therefore, the following auxiliary equation can be obtained:

$$S_{rit} = \pi_i + \pi_1 X_{r,u} + \pi_2 X_{r,y} + \pi_1' X_{r,u} q_{t-d} + \pi_2' X_{r,y} q_{t-d} + \eta_{it}, \quad (6)$$

where $d = 0, 1, \ldots, 5$ to allow the present term rate of change of economic growth rate. The PSTR model proposed by González et al. [30] was used to test nonlinearity, and its formula was represented by formula (3). Testing the sample model was needed to see if it reported its nonlinear effect. The null hypothesis of that model was as follows.

H0: $\pi_1' = \pi_2' = 0$.

First, the null hypothesis of one transfer function and opposing hypothesis of two transfer functions were tested. If the test result rejected the null hypothesis, the next step was to test the null hypothesis of two transfer functions and the opposing hypothesis of three transfer functions. The test process continued until the first appearance that the null hypothesis could not be refused. For the test of statistical quantity, according to Fouquau et al. [40], three methods, namely, the Fisher, Wald, and likelihood ratio tests, were adopted. In this study, linearity and no-remaining nonlinearity tests were conducted.

PSSR0 of model (7) represented, under the null hypothesis, the panel sum of residual squares in the linear panel model with individual effect. PSSR1 represented, under other choices, the panel sum of residual squares of PSTR models with two statuses. The corresponding statistical model of the Lagrange multiplier (LM) was as follows:

$$LM_F = \frac{\left[\left(PSSR_0 - PSSR_1\right)/K\right]}{\left[PSSR_0/\left(TN - N - K\right)\right]}, \quad (7)$$

where K is the number of independent variables. Under the null hypothesis, the statistical quantity of LM_F was of $x^2(k)$ distribution. F statistical quantity approached $F(mk, Tn - n - mk)$ distribution.

4. Empirical Analysis and Results

4.1. Descriptive Statistics. The research period of this study was from 2001 to 2019, the data structure was panel time series, and the objective was to investigate nonlinear factors

Table 3: Descriptive statistics of research variables.

Variable	Max	Min	Mean	Std. dev.
S_r	0.4845361	−0.9473684	−0.1591002	0.3140311
E_r	14.65714	−34.5125	−2.545459	6.224092
U_r	0.5190312	−7.611308	−1.726858	2.548899
C_r	1.145975	−0.1257736	0.3095667	0.4703767

Note. (1) S_r is the rate of change of suicide rate; E_r is the rate of change of economic growth rate; U_r is the rate of change of unemployment rate; C_r is the rate of change of crime rate. (2) The research period was from 2001 to 2019.

Table 4: Correlation coefficient analysis table of Taiwan's entire economic growth rate and other independent variables.

	Sr	Er	Ur	Cr
Sr	1.0000			
Er	0.2032	1.0000		
Ur	0.8553	0.4151	1.0000	
Cr	−0.8683	−0.3384	−0.9724	1.0000

Note. (1) The same as Table 3. (2) The same as Table 3.

affecting Taiwan's suicide rate. Before analysing the regression results, first, the basic prospect of the data structure was inspected. Then, the maximal value, minimal value, mean value, and standard deviation of each variable were discussed. The total number of samples was 57. The descriptive statistical data of the entire sample number were arranged as in Table 3.

4.2. Collinearity Test and Variance Inflation Coefficient Analysis. In this section, the collinearity issue among the independent variables was independently inspected. For the judgment of this issue, correlation is a method used to evaluate the correlation of two variables, such as X and Y. It is a method to confirm the correlation of two existing variables. Furthermore, based on the understanding of one variable, another variable was predicted. Collinearity occurs when two or more independent variables were not mutually independent; that is, collinearity existed between them. Collinearity will lead to the existence of repeated independent variables in the regression model, and the explanatory power and prediction power of certain independent variables will be enhanced, resulting in incorrect construction of theory.

However, for the collinearity of the independent variable, the range of the correlation coefficient was from 0 to 1. Grewal, Cote, and Baumgartner [41] thought that when the maximal critical value of collinearity was 0.95, the independent variables will have a collinearity issue. By contrast, Cooper and Schindler [42] set the threshold at around 0.8. To study the conscientiousness of the variables, the stricter standard system was adopted in this study, and 0.8 was used as a basis for judging if collinearity existed among independent variables.

The test of collinearity among independent variables was as shown in Table 4. To confirm again if collinearity existed among the independent variables, variance inflation factor analysis was further used to judge if the independent variables of the multiple linear regression model were independent of each other. When the value of the variance inflation coefficient was significantly larger than 10, it meant that collinearity occurred among these independent variables. Such independent variables were included in empirical analysis. Table 5 shows that the rate of change of suicide rate and the rate of change of unemployment rate and the rate of change of crime rate, after variance inflation coefficient analysis, were 1.17 and 1.11, respectively, and both of them did not exceed the critical test value of 10. This meant that neither had a collinearity issue and would not affect empirical analysis.

4.3. Panel Unit Root Test. Before carrying out the empirical model, whether the data within the overall variables are a stable series was tested to avoid the generation of spurious regression in the estimation result. This study followed the steps of the panel unit root test method proposed by Levin et al. [43], known as the LLC test, to test whether the attribute of a related variable is stationary or nonstationary data. The LLC test also considers cross section and time series data to solve the insufficient data number issue, thereby enhancing the test power. Specifically, the LLC test had the following hypotheses:

(i) H0: all variables had unit root.

(ii) H1: all variables did not have unit root (variables were all stationary).

If the empirical result showed that the P value of a variable was significant, then the null hypothesis was rejected and the opposing hypothesis was accepted. The test result is shown in Table 6.

The statistical quantity and P value of Table 6 show that the test results for all variables were significant, indicating that H0 was rejected and H1 was accepted. The hypothesis indicated that not having unit root was acceptable. Therefore, in the panel data, through cross section and time series, the variables were a stable series. The result also proved that a nonlinearity test can be conducted.

4.4. Empirical Analysis

4.4.1. Linear Test. As shown in the test result of the panel unit root test, all the variables achieved consistency with a stable series. Therefore, the study tested if the model logic conforms to a nonlinear correlation among the rates of change of suicide, unemployment, and crime rates. First, the hypothesis regarding linearity was inspected, as was the correlation among the three rates of change, to see if it is nonlinear or linear:

(i) H0: $\theta_1' = \theta_2' = 0$ (linear model).

(ii) H1: $\theta_1' \neq \theta_2' \neq 0$ (PSTR model with at least one transfer function).

If the linear null hypothesis was rejected, then the next step was to aim at a double dynamic value model to test the null hypothesis of the single dynamic value model. The test

Table 5: Variance inflation coefficient table of Taiwan's entire economic growth rate and other independent variables.

Variable	VIF	1/VIF
Ur	1.17	0.852830
Cr	1.11	0.899387
Er	1.09	0.917920
Mean VIF	1.12	

Note. (1) The same as Table 3. (2) The same as Table 3.

Table 6: Test result of the panel unit root test.

Method	Statistic	Prob
ADF—Fisher chi-square	18.6542	0.0048***
ADF—Choi Z-stat	−2.08391	0.0186**

Note. (1) The sample adoption period was from 2001 to 2019. (2) The symbols *, **, and *** meant, respectively, that they were significant under significance levels of 10%, 5%, and 1%.

Table 7: Linear test result.

Test statistic	Number of location parameters (m)	
	$m = 1$	$m = 2$
Wald tests (LM)	4.655(0.098)*	7.561(0.109)
Fisher tests (LMF)	1.601(0.216)	1.300(0.290)
LRT tests (LRT)	4.856(0.014)**	8.112(0.000)***

Note. (1) The number in parenthesis meant P value. (2) The symbols *, **, and *** represent, respectively, they were significant under significance levels of 10%, 5%, and 1%.

Table 8: No-remaining nonlinear test results.

Testing statistic	Number of location parameters (m)	
	$m = 1$	$m = 2$
Wald tests (LM)	1.938(0.379)	2.441(0.655)
Fisher tests (LMF)	0.563(0.575)	0.336(0.852)
LRT tests (LRT)	1.972(0.373)	2.495(0.646)

Note. (1) The number in the parenthesis represented P value.

included the following two situations. In the first, the location parameter results of the first and second tests were used. In the second situation, the result of the first situation was reconfirmed, and this meant that the result was more trustable. The linear test result is shown in Table 7.

Statistical analysis of the linear test in Table 7 shows that, under the first test situation, for the test result of the Wald test with confidence region of 90% and LRT test with confidence region of 95%, the significance was 0. Under the second test situation, for the test result of LRT test of confidence region of 99%, the significance was also 0. This value was the most significant; as long as one of the results was significant, the linear null hypothesis was refused. This estimation result clearly shows that the correlation among the rate of change of suicide rate, rate of change of unemployment rate, and rate of change of crime rate was nonlinear. Furthermore, the data structure of this study was nonlinear.

4.4.2. Optimal Quantity Test of the Dynamic Value Variable. Once the estimation model was confirmed as nonlinear and under smooth transformation, the number (r) of transfer function needed to be confirmed. In other words, a no-remaining nonlinear test should be conducted. After two repeated change tests on the null and opposing hypotheses, reliability is ensured. The result is shown in Table 8. The relationship among rate of change of suicide rate, rate of change of unemployment rate, and rate of change of crime rate was not linear. Therefore, the optimal quantity of dynamic value variable was further analysed, and the hypotheses were as follows:

(i) H0: PSTR model with one dynamic value variable ($r = 1$).

(ii) H1: PSTR model with two dynamic value variables ($r \geq 2$).

According to the results of three statistical quantity tests, regardless of whether the location parameter was one ($m = 1$) or two ($m = 2$), all the test data cannot significantly reject the null hypothesis. Therefore, the PSTR model had only one transfer function ($r = 1$). In other words, the PSTR model with $r = 1$ and $m = 1$, and $r = 1$ and $m = 2$ was used for estimation. However, the optimal estimation model quantity of that model was only one, and its judgment standard was the smallest Akaike information criterion (AIC) value and Bayesian information criterion (BIC) value. The estimation result is shown in Table 9.

4.5. Empirical Results. In this section, the PSTR model proposed by González et al. [30] is used to investigate, under the variation of economic growth rate, the nonlinear smooth transition effect of rates of change of unemployment and crime rates on the rate of change of suicide rate. In addition, to verify the difference between the PSTR model and the traditional linear model, the result of the latter was further estimated. The empirical results are shown in Table 9.

4.5.1. Panel Smooth Transition Regression Model. González et al. [30] pointed out that, empirically, just one or two dynamic values were sufficient to compensate for the nonlinear phenomenon. Therefore, when empirical analysis was conducted in this study, the number of dynamic values was assumed to be at most two. Under the situation in which rate of change of economic growth rate was the transformation variable, the estimation result of the PSTR model was as shown in Table 9. The table indicates that the transformation speed (r) and dynamic value (c) were 615.6195 and −3.0098, respectively. When transformation variable > dynamic value −3.0098, the relationship between the independent and dependent variables was positive. When transformation variable < dynamic value −3.0098, the relationship between the independent and dependent variables was negative. The detailed description between the variables is listed below. The influence of rate of change of unemployment rate to rate of change of suicide rate was significantly positive ($-0.0969 + 0.2964 \times G(S_r; 615.6195, -3.0098) > 0$); that is, under extreme values of transfer

Table 9: Empirical results of PSTR and linear models.

Model parameter	PSTR model	Linear panel data model
C	—	0.0227339(0.0253324)
θ_1	−0.0969(0.0347)***	0.0247965(0.0354634)
θ_1'	0.2964(0.0715)***	—
θ_2	−1.3009(0.2177)***	−0.4490601(0.1921708)**
θ_2'	1.4879(0.3486)***	—
R	615.6195	—
C	−3.0098	—
N	57	57
AIC	−4.2657	—
BIC	−4.0506	—
R-squared	—	0.7562
Hausman test	—	0.2474

Note. (1) The transformation variable in PSTR was rate of change of economic growth rate. (2) θ_1 and θ_1' were the rate of change of unemployment rate. (3) θ_2 and θ_2' were rate of change of crime rate. (4) $\theta_1 + \theta_1' = 0.1995, \theta_2 + \theta_2' = 0.187$. (5) The symbols *, **, and *** represented, respectively, that they were significant under significance levels of 10%, 5%, and 1%.

function of 0 and 1, 10% and 3% rates of change of suicide rate were expanded, respectively. This meant that, in the PSTR model, facing two extreme statuses, $G(E_r; 615.6195, -3.0098) = 0$ and $G(E_r; 615.6195, -3.0098) = 1$, the influences were $\theta_1(-0.0969)$ and $\theta_1 + \theta_1'(0.1995)$, respectively. Generally, a lower R-squared value represented a higher rate of change of unemployment rate. Therefore, if rate of change of unemployment rate was enhanced, then the positive coefficient 0.1995 represented a negative influence on rate of change of suicide rate. In addition, the effect of rate of change of crime rate on rate of change of suicide rate was $(-1.3009 + 1.4879 \times G(S_r; 615.6195, -3.0098) > 0)$; that is, under the extreme values 0 and 1 of transfer function, the effect was respective expansion of 13% and 15% of rate of change of suicide rate. In other words, under two extreme values, that is, $G(E_r; 615.6195, -3.0098) = 0$ and $G(E_r; 615.6195, -3.0098) = 1$, the influences were, respectively, $\theta_2(-1.3009)$ and $\theta_2 + \theta_2'(0.187)$, which was insignificant. This showed that when the fluctuation of rate of change of economic growth rate rose, the influence of rate of change of crime rate on rate of change of suicide rate was enhanced.

4.5.2. Linear Model. In this section, the PSTR model is used to estimate the suicide rate of the entirety of Taiwan. The estimation results of the traditional and PSTR models are compared. In the linear model, a Hausman test was used to test whether the fixed effect or random effect models were applicable to data type. If the test result refused H0, then correlation existed between the dependent variable and independent variable in all of Taiwan, and the fixed effect model was thought of as effective and consistent. Therefore, the adoption of the fixed effect model in empirical estimation was more applicable. If the test result did not reject H0, then correlation did not exist between dependent and independent variables in all of Taiwan. Therefore, the random effect model should be used as the empirical model. For the Hausman test, its P value was 0.2474. Therefore, the data type used in the empirical model should be the random effect model. In Table 9, the coefficient of rate of change of unemployment rate was 0.0247965, indicating that its influence was not significant. The coefficient of rate of change of crime rate was −0.4490601, indicating that its influence was significant and negative.

Notably, when the linear model was used in empirical estimation, it will lead to deviation in the estimation result. For example, in the linear panel data model, the influence of rate of change of unemployment rate on rate of change of suicide rate was fixed at 0.0247965. However, under the PSTR model, its influence was dependent on whether the transformation variable was lower or higher than the dynamic value (−3.0098). Furthermore, based on the type of different transformation variables $G(E_r; 615.6195, -3.0098) = 0$ and $G(E_r; 615.6195, -3.0098) = 1$, the effects were, respectively, −0.0969 and 0.1995. When the linear panel data model was used, it cannot clearly reflect the correlation between rate of change of suicide rate and rate of change of unemployment rate, unlike the PSTR model. For the influence of rate of change of crime rate on rate of change of suicide rate, a similar result was obtained. Therefore, the PSTR model was more appropriate than the linear panel data model.

Generally, the correlation between the independent and dependent variables was nonlinear. In transfer function status, the transformation dynamic value c and transformation speed γ were −3.0098 and 615.6195, respectively. In addition, in the development of economic growth rate, a marginal influence of rate of change of unemployment rate and crime rate on rate of change of suicide rate was found. This indicated that the rate of change of economic growth rate might have a nonlinear influence on rate of change of suicide rate. Finally, when the dynamic value was smaller than −3.0098, the reduction of rate of change of unemployment rate or crime rate will have an aggressive influence on rate of change of suicide rate. In addition, the effect of reducing the rate of change of unemployment rate was more significant than the reduction of rate of change of crime rate.

5. Conclusion

In this study, the PSTR model was adopted to study the nonlinear correlation among unemployment rate and crime rate on suicide rate. The adjusted formula for rate of change was used as the basis for empirical analysis, and economic growth rate was used as the dynamic value. According to the empirical result, three conclusions can be drawn. First, the existence of a dynamic value on that model can prove the existence of a nonlinear relationship. Second, when exceeding the dynamic value, the influence of unemployment rate and crime rate on suicide rate was aggressive. Whenever one unit was increased in unemployment rate and crime rate, the increase in suicide rate would increase by 5.0125 and 5.3476 units, respectively. Third, when under dynamic value, the influence of change of unemployment rate and crime rate on suicide rate was negative. Whenever unemployment rate and crime rate were increased by one unit, suicide rate dropped by 10.3199 and 0.7687 units,

respectively. Generally, the influence of rate of change of unemployment rate and rate of change of crime rate on rate of change of suicide rate was nonlinear. When transformation variable was lower or higher than its estimated dynamic value, the relationship between independent variable and dependent variable showed a reverse trend.

In recent years, more and more studies have investigated the influence of unemployment rate and crime rate on suicide rate. If a country can maintain the development of its economic growth and increase work opportunities to reduce the national unemployment rate, then the crime rate will be reduced and the possibility of the occurrence of domestic suicide rate can be reduced. In addition, for the subsequent research direction, because this study only singly focused on the investigation of the dynamic effect of the influence of unemployment rate and crime rate on suicide rate under the economic growth rate of Taiwan, gender was not taken out independently for analysis. Therefore, in future, in-depth research can be focused on male and female subjects, in situations of unemployment and crime, with the intention of selecting suicide. In addition, many studies have focused on the use of the divorce rate, women's labour participation rate, minimal wage rate, and social welfare system as independent variables to investigate their influences on suicide rate. Therefore, in future research, related variables or the deaths of despair hypothesis can be extended to investigate the corresponding suicide rate result.

Two limitations of this study were identified. In the data structure part, the dependent variable of this study was suicide rate and the minimum statistical unit of its data structure was annual data. Therefore, to meet the research need, the transformation and independent variables of this study needed to be changed into annual data. In the research year part, for the suicide rate data of the dependent variable of this study, the collectable data period was 1994 to 2019. For the crime rate data in the independent variable, the collectable data were in the period from 2000 to 2020. Therefore, to meet the research need, other variables needed to conform to the data period of suicide rate and crime rate, so that the research period of each variable can be consistent. The research period of this study was annual data from 2000 to 2019.

Data Availability

Data are available on request from the corresponding author.

Conflicts of Interest

The authors declare no conflicts of interest.

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