Relationship between Sports Consumption and Economic Growth based on A State-space Model

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Abstract

Research has focused on the application of state-space models to economics. -Such models are also known as dynamic system theory, which assumes that the studied system is decided by an unobservable vector sequence over time. Sports consumption is an important aspect of sports economics and of consumption in modern living. As the economy develops, the social consumption mode and economic structure change significantly, and sports consumption displays good market demand. By establishing the state-space model in relation to sports consumption and economic growth, this thesis verifies and estimates the model parameters and concludes that sports consumption increases by 0.431%—0.439% when Gross Domestic Product (GDP) increases by 1%.

Keywords: State-space model, Model test, Economic development, Sports consumption

1 Introduction

The state-space model is also known as dynamic system theory, which assumes that the studied system is decided by an unobservable vector sequence over time [1]. This sequence is related to an observable sequence. Changes in the unobservable sequence can be inferred by statistically studying the observable sequence [2]. The variation trend of the entire system is thus obtained [3]. This model is usually applied to the study of economic phenomena; the variation tendency of the stem is obtained through modeling and evaluation, thereby facilitating the determination of how "the invisible hand" controls macro-economic phenomena [4]. The state-space model provides feasible research methods for many fields, including economic measurement, finance, and energy consumption [5]. All of these research fields are analyzed based on time sequence, as with sports consumption.

In the 21st century, sports consumption significantly expands and drives the increase of domestic demands [6]. The sports industry is highly active in some developed countries. Therefore, business modes with different features have been developed after many years of operation and exploration [7]. Furthermore, the contribution of sports industrialization to the national economy is considerable; sports consumption contributed 1% to the total GDP of America in the 1980s. The rate has increased to 2% in the 21st century, and this industry ranks 11th among all industries [8]. In addition, sports consumption accounts for 1%—1.5% of the total GDPs in Britain, Spain, France, Germany, Italy, and Japan. However, the sports consumption of China is insufficient and has much room for improvement, according to Yang Yue et al. Specifically, sports consumption should be granted a similar level of importance with fields such as culture, tourism, and education with respect to policy-making [9]. The sports industry can enhance the quality of life given that people pursue healthy lifestyles under the rapid economic development in China. If the pursuit for a high quality of life is limitless, then the same should be true for the growth space of sports consumption [10]. Du Jianhui observed that sports consumption can drive economic development considerably, expand domestic demands, and ensure the rapid and stable development of the national economy; consequently, the degree recognition of sports consumption improves as well. Therefore, the overall improvement in the quality of life in the nation depends on the development of sports field. In the current study, we employ mathematical models to clarify the relationship between sports consumption and economic development fundamentally [11]. The application of such models is typically popular worldwide. Therefore, we identify a mode that can analyze economic phenomena, that is, the state-space model, for application to this thesis.

The state-space model is widely applied to economics [5]. For instance, Hamilton, Kim, and Nelson investigated the methods of state-space modeling intensively. Han Dongmei et al. applied the state-space model to study the foam of real estate price [4]. They also determine commercial housing prices in Shanghai that have deviated from their basis value and the increase in the foam degree of real estate in Shanghai to 22.5%. They then propose corresponding countermeasures for the phenomenon. Yu Yanping et al. examined the relationship among money supply, price level, and macro-economic growth using the state-space model, which is also a good analytical tool that can effectively examine such relationships among variables [12]. Nonetheless, few studies have applied the state-space model to the relationship between sports consumption and economic growth. The occupancy volume of sports consumption in GDP cannot be ignored; thus, the current research establishes a state-space model for the relationship between sports consumption and economic growth to establish a theoretical basis for the contribution of the former to the latter and to provide a basis on which related

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policies may be develop to guide real life significantly.

2 Theory of the state-space model

2.1 DEFINITION OF THE STATE-SPACE MODEL

The vector group $\vec{x_t}$ is known as the state variable of the system and is used to describe the internal features of the system at moment t . This variable is random and unobservable. Furthermore, its value is derived from points in the N_x Euclidean space, i.e., $\vec{x_t} \in \mathbb{R}^{N_x}$, where $\mathbb{R}^{N_x}$ denotes the state-space.

The state is a flexible and changeable concept and is significantly advantageous when applied to multivariable systems. System state variables can reflect the changes in the system features over time. The state vector is practically, physically, or economically significant in numerous applications. However, state variables take different forms for various objects. For convenient modeling, relatively advantageous forms are selected to for analog computation.

We also define the observational variable y_t . The different definition methods share similar aspects, and we must choose corresponding forms for a convenient analysis and simplified calculation of the study objects.

2.2 CLASSIFICATION OF THE STATE-SPACE MODEL

The state-space model consists of two important equations, i.e., state and observation equations. Specifically, the state equation expresses the relationship between the system state at the moment and that at the next moment, whereas the observation equation describes the relationship between the observed sequence and the system state. When the two equations are combined, the internal system variation trend can be obtained. The state-space model is simple classified as follows:

(1) Non-linear state-space model

$$\begin{aligned} x_t &= f\left(x_t,\eta_t,\theta\right) \\ y_t &= h\left(x_t,\varepsilon_t,\theta\right) \end{aligned} \tag{1}$$

We generally assume that the system process can be superposed, i.e.

$$\begin{aligned} x_t &= f\left(x_t,\theta\right)+\eta_t \\ y_t &= h\left(x_t,\theta\right)+\varepsilon_t \end{aligned} \tag{2}$$

The model is a special case of the hidden Markov model as per a re-representation of the foregoing process:

$$\begin{aligned} p_\theta\left(x_t \middle| x_{t-1}\right) &= p_{\eta_t}\left(x_t - f\left(x_{t-1},\theta\right)\right) \\ p_\theta\left(y_t \middle| x_t\right) &= p_{\varepsilon_t}\left(y_t - h\left(x_t,\theta\right)\right) \end{aligned} \tag{3}$$

We may also use a similar form to express system process when it cannot be superimposed. Its principle involves converting probability density using a function. We can then obtain:

$$\begin{aligned} p_\theta\left(x_t \middle| x_{t-1}\right) &= p_{\eta_t}\left(f^{-1}\left(x_t,x_{t-1},u_t,\theta\right)\right)\cdot\left|\det\left(\nabla_{x_t}\left(f^{-1}\right)^T\right)\right| \\ p_\theta\left(y_t \middle| x_t\right) &= p_{\varepsilon_t}\left(h^{-1}\left(y_t,x_t,u_t,\theta\right)\right)\cdot\left|\det\left(\nabla_{y_t}\left(h^{-1}\right)^T\right)\right| \end{aligned} \tag{4}$$

$$p_\theta(y_{t:T}|x_{t:T}) = \prod_{i=t}^{T} p_\theta\left(y_i \middle| x_i\right) \approx \prod_{i=t}^{T} p_{\varepsilon_t}\left(y_t - h\left(x_t,\theta,t\right)\right) .$$

Specifically, $1 \le t \le T$ exists for any t.

(2) Linear/non-linear mixed model

The non-linear state-space model is complicated to process in general. Therefore, we usually discuss only special cases. If the non-linear model contains decomposable factors, then we may use the marginalization particle filter method. This method primarily decomposes non-linear parts, i.e.

$$\begin{aligned} x^n_{t+1} &= A^n_{n,t}x^n_t + A^n_{l.t}x^l_t + G^n_t\eta^n_t \\ x^l_{t+1} &= A^l_{n,t}x^n_t + A^l_{l.t}x^l_t + G^l_t\eta^l_t \\ y_t &= h\left(x^n_t,t\right)+\varepsilon_t \end{aligned} \tag{5}$$

where $w^n_t \sim N\left(0,Q^n_t\right)$ and $\eta^l_t \sim N\left(0,Q^l_t\right)$. ε_t is presumably known and distributed randomly.

(3) Linear state-space model

The linear state-space model is the simplest and the most common model. Its structural form is shown as follows:

$$\begin{aligned} x_{t+1} &= A_t\left(\theta\right)x_t + \eta_t \\ y_t &= C_t\left(\theta\right)x_t + \varepsilon_t \end{aligned} \tag{6}$$

where $\eta_t \sim N\left(0,Q_t\left(\theta\right)\right)$, $\varepsilon_t \sim N\left(0,R_t\left(\theta\right)\right)$, and $E\left\{\eta_t\varepsilon_t^T\right\}=0$.

This equation also corresponds to a simple classification of the state-space model. Although the various forms and research frameworks of state-space models are similar, the different types of models differ significantly in terms of the selection of corresponding algorithms. Thus, this thesis mainly investigates the linear state-space model. Our study also builds models and selects algorithms based on this model. The system law in relation to observable variables is determined by analyzing the phenomena.

2.3 EXPRESSION OF THE PRACTICAL APPLICATION OF THE STATE-SPACE MODEL

The state-space model is highly effective when applied to different economic fields. Its expressions differ according to research object. Accordingly, some practical model forms are extracted from numerous applications. The typical forms in which the state-space model is applied in economics are given as follows (e.g., the partial linear trend and time-varying parameter models):

(1) Partial linear trend model

$$\begin{aligned} & y_t = \mu_t + \beta_t + \varepsilon_t && \varepsilon_t \sim iid\ N\left(0,\sigma_\varepsilon^2\right) \\ & \mu_t = \mu_{t-1} + \beta_{t-1} + \eta_t && \eta_t \sim iid\ N\left(0,\sigma_\eta^2\right) \\ & \beta_t = \beta_{t-1} + \varsigma_t && \varsigma_t \sim iid\ N\left(0,\sigma_\varsigma^2\right) \end{aligned} \tag{7}$$

Where μ_t and β_t represent the horizontal and inclined trends, respectively. In the state-space model, these trends are expressed in the following forms:

$$y_t = \begin{bmatrix}1 & 0\end{bmatrix}\begin{bmatrix}\mu_t \\ \beta_t\end{bmatrix} + 0 + \varepsilon_t \tag{8}$$

$$\begin{bmatrix}\mu_t \\ \beta_t\end{bmatrix} = \begin{bmatrix}1 & 1 \\ 0 & 1\end{bmatrix}\begin{bmatrix}\mu_{t-1} \\ \beta_{t-1}\end{bmatrix} + 0 + \begin{bmatrix}\eta_t \\ \varsigma_t\end{bmatrix} \tag{9}$$

Equations (4) and (5) are the observation and state equations, respectively.

(2) Time-varying parameter model

$$y_t = x_t'\beta_t + \varepsilon_t\ , \quad \varepsilon_t \sim iid\ N(0,\sigma_\varepsilon^2) \tag{10}$$

$$\beta_t = \beta_{t-1} + \eta_t\ , \quad \eta_t \sim iid\ N(0,\sigma_\eta^2) \tag{11}$$

Equations (6) and (7) are the observation and state equations, respectively. Furthermore, the model is widely applicable and can be used to build other models. It is characterized by state parameters that are a function of time *t*, and many economic phenomena actually belong to this type. By building and studying such models, we determine the variation trend of the system in terms of time and predict future economic phenomena. The obtained results can guide production and quality of life. In this thesis, the model is adopted in this form for theoretical analysis.

(3) Autoregressive—moving—average (ARMA) model

Given the ARMA *(p,q)* model:

$$y_t = \varphi_1 y_{t-1} + \cdots + \varphi_p y_{t-p} + \varepsilon_t + \theta_t \varepsilon_{t-1} + \cdots + \theta_q \varepsilon_{t-q} \tag{12}$$

let $m = \max(p, q+1)$. The foregoing model may then be re-written in the following form:

$$y_t = \varphi_1 y_{t-1} + \cdots + \varphi_m y_{t-m} + \varepsilon_t + \theta_t \varepsilon_{t-1} + \cdots + \theta_{m-1} \varepsilon_{t-m+1} \tag{13}$$

Some coefficients may be 0. In this case, the ARMA model may be expressed in the following form:

$$y_t = \begin{bmatrix}10\cdots0\end{bmatrix} x_t \tag{14}$$

$$x_t = \begin{bmatrix}\varphi_1 & 1 & 0 & \cdots & 0 \\ \varphi_2 & 0 & 1 & \cdots & 0 \\ \vdots & \vdots & & \ddots & \vdots \\ \varphi_{m-1} & 0 & 0 & \cdots & 1 \\ \varphi_m & 0 & 0 & \cdots & 0\end{bmatrix} x_{t-1} + \begin{bmatrix}1 \\ \theta_1 \\ \vdots \\ \theta_{m-1}\end{bmatrix} \varepsilon_t \tag{15}$$

Equations (10) and (11) are the observation and state equations, respectively.

The model forms applied to the state-space model in economy and finance also include partial level, ARMA, and stochastic volatility models. The state-space model is highly vital and flexible as a practical tool for simple analysis. It is modeled through a wide range of highly flexible modeling methods. Thus, the model can be used to enhance developments in future economic analysis.

3 Empirical analysis of state-space model construction

The research objects are the GDP values and the total retail sales of consumer goods (sports and entertainment goods) in the wholesale and retail trade industry from 1990 to 2010. Data are collected from the China Statistical Yearbook and the statistical database of CEInet.

3.1 ESTABLISHMENT OF THE STATE-SPACE MODEL

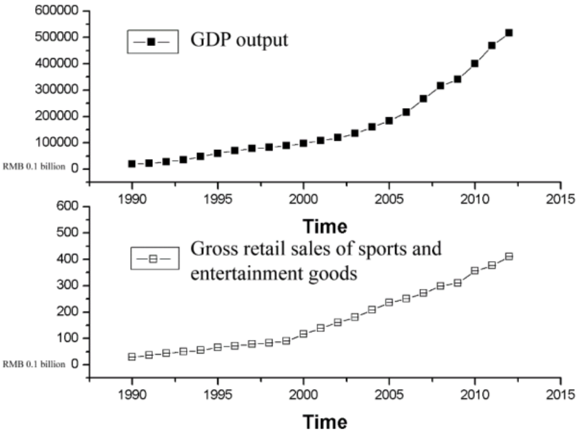

FIGURE 1. Total GDP output and the trend of the gross retail sales of sports and entertainment goods in the wholesale and retail trade industry

The practical data on GDP, which were collected from 1990 to 2010, are high credible. The model is constructed after the natural logarithm has been determined for practical GDP and the gross retail sales of sports and entertainment goods to eliminate errors caused by heteroskedasticity. The model is expressed as follows:

$$ln\left(ACS_t\right) = \beta_t * ln\left(GDP_t\right) + c(1) + \left[\text{var} = e^{c(2)}\right] \tag{16}$$

$$\beta_t = \beta_{t-1} \tag{17}$$

Table 1 presents the specific results after estimation and fitting.

TABLE 1 Results of parameter estimation and fitting

	Constant	Standard deviation	Value of *Z*	Value of *P*
C(1)	4.659023	0.364866	12.67325	0.0000
C(2)	-4.349385	0.312274	-13.35446	0.0000
	Final state *e*	Deviation	Value of *Z*	Value of *P*
β	0.435670	0.004546	305.4642	0.0000

The probability value of all parameters is 0. Thus, the significance of the model can be identified based on its coefficients and parameters. The sequence correlation of the model may be ignored with respect to residual error. The standard deviations of parameters are indicative of other factors. Furthermore, economic growth level also affects the relationship between sports consumption and economic development.

We should test the model to ensure the reliability of its results. The co-integration relationship of the model with regard to parametric variation is dynamic, which differs to some extent from those of other models.

3.2 TEST OF MODEL STRUCTURE

3.2.1 Chow test

To verify the proportional relation between sports consumption and economic development, β_t is assumed to be a constant in the interval of research samples. The model parameter is constant in the interval, and the model form is expressed as follows:

$$ln\left(ACS_t\right)=\beta\cdot ln\left(GDP_t\right)+c+u_t \tag{18}$$

Figure 1 depicts an increasing trend for both sports consumption and GDP. However, the growth in GDP took place from 1999 to 2001, which may be related to the sports policy adopted by China when it applied to hold the Olympic Games. As a result, the trend of sports consumption increased rapidly in China. GDP growth also peaked from 2007 to 2010, which is directly associated with the Beijing Olympic Games and with the increasing interest in national fitness. Thus, we may assume that the year 2008 is a discontinuity point of our hypothesis. Moreover, the Chow test is used to verify the function stability of Equation (14). Table 2 presents the test results.

TABLE 2 Results of the Chow test

Statistical variable	Statistical value	Standard deviation	Value of *P*
F statistical value	34.38324	0.36405	0.0000
Maximum likelihood	39.12324	0.38453	0.0000
Wald statistical variable	69.23235	0.68435	0.0000

The F statistical value is significantly higher than the critical value (5%), and value of *P* (0), which imply that sports consumption underwent considerable structural changes around 2008. Thus, we may establish a variable parameter model for sports consumption.

3.2.2 Co-integration test

This study applies the two-step method of the Engle—Granger (EG) co-integration test. First, the model is estimated. Subsequently, its stationarity is tested. If the accuracy of a co-integration equation is confirmed, then the test results are represented by a stable time sequence. A residual sequence is obtained using the EG method and special analysis software. We also implement the Augmented Dickey—Fuller (ADF) test according to the relationship between sports consumption and economic growth. Table 3 presents the related results.

TABLE 3 ADF test of residual errors

Sequence name	1% significance level	5% significance level	8% significance level	10% significance level	Value of *P*	Conclusion
Residual error	-4.546236	-3.758937	-2.768373	-2.596745	0.00045	Stable below 5%

The level at which the residual sequence is stable can be maintained at below 1%. Thus, the estimated and simulated values generated for the variable parameter model may be regarded as reliable. Therefore, a proportional relationship exists between sports consumption and economic growth, and its balance accords with the co-integration relationship. Consequently, the results obtained using the model and the estimated values have reference value. Moreover, their rationality is within the error range.

3.3 ESTIMATION OF THE STATE-SPACE MODEL

Based on the data in Table 1, the obtained fluctuation range of β is 0.431—0.439, with an average value of 0.786. Hence, sports consumption increases by 0.431%—0.439% when GDP increases by 1%. Therefore, the elastic coefficient of sports consumption β can be used to analyze the size and capability of sports consumption in different periods. The changes in GDP growth are closely related to the sports consumption in a corresponding period. Consequently, the established model is reliable.

Opinions on sports consumption are civilized by the daily development of large-scale sports activities and projects, as per Figure 1. The input of the country's resources into sports facilities accelerates during this development period, and all-people movement upsurges. When quality of life improves gradually, people begin to pursue healthy lifestyles. The model results can be applied effectively to practical situations, given the corresponding increase in the value of β during this period.

As a result of data limitation, this thesis considers the gross sales of sports and entertainment goods in the retail industry to be the object of research on sports consumption. This variable is not adequately comprehendsive; nonetheless, the statistics on sports goods are typically presented alongside those of other entertainment goods, according to official statistical data. Therefore, no special statistics are generated for sports consumption. As a result, the obtained results may deviate slightly. For instance, we cannot separate sports consumption from entertainment consumption in the model, and we must unreasonably treat entertainment consumption as sports consumption. Thus, related departments should separate the statistics on sports consumption from those on entertainment consumption during conducting statistical analysis on these aspects. Furthermore, persuasion should be enhanced for theoretical analyses on the obtained single data related to sports consumption. The analysis presented in this thesis is significant, highly reliable, and provides a reference for specific analysis in the future.

4 Conclusion

This thesis establishes a variable parameter model that reveals the relationship between sports consumption and economic growth. As per a validation analysis of model parameters, sports consumption increases by 0.431%–0.439% when GDP increases by 1%.

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