Research and Analysis on the Identification Model of Multivariate Economic System

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Abstract. For the regional economic development of macroeconomics, which is restricted by many variables or factors, this paper establishes a multi-variable economic system identification model, analyses the established multi-variable economic system identification model, and the identified model is basically the same as the real model. Finally, Using MATLAB to identify the multi-variable economic system identification model, the simulation results show that the recognition Economic Management Identification Curve and Original economic management input curve recognition are consistent, demonstrating that the method of identifying the multi-variable economic system is correct and meets the needs of economic development. It has a strong reference value. The simulation results verify the feasibility and effectiveness of the proposed identification and modeling method.

1. Introduction

Any macroeconomic mathematical model is a combination of an economic theory and a mathematical method to describe the quantitative relationship between the main parameters of the object [1-3], so as to achieve the purpose of analysis, prediction, evaluation or decision-making. It is a basic task to analyze the economic system by using the economic mathematical model to describe the dynamic characteristics of the economic system [5-7]. However, most economic systems are difficult to establish mathematical models by analyzing the complexity of thousands of structures and the limitations, fuzziness, and incompleteness of information of economic theories. Therefore, the theory and method of constructing economic mathematical model by using observation data have been paid attention to macroeconomic mathematical model.

The multi-variable controlled regressive sliding average (CARMA) model is a kind of model that is widely used in forecasting field [8-9], especially its special form CAR model, which is most commonly used in practical applications. The literature [10] proves that any multivariate CARMA model can be approximated to any accuracy by a CAR model with a sufficiently high order. So we use CARMA model, which is more convenient than CARMA model [11-36], to model the multivariable economic system uniformly.
This paper establishes a multi-variable economic system identification model, analyzes the established multi-variable economic system identification model, and the identified model is basically the same as the real model. Finally, using MATLAB to identify the multi-variable economic system identification model, the simulation results show that the recognition Economic Management Identification Curve and Original economic management input curve recognition are consistent, demonstrating that the method of identifying the multi-variable economic system is correct and meets the needs of economic development. It has a strong reference value. The simulation results verify the feasibility and effectiveness of the proposed identification and modeling method.

This identification method can also be used for N variable economic systems. In order to make the economic mathematical model describe the economic phenomenon more fundamentally, the identified model must satisfy certain economic theories such as consumption, investment, accumulation, and circulation.

2. Multi-variable economic system identification model

The actual system can be described by the following model

\[
A(z^{-1})y(t) = z^{-k}B(z^{-1})u(t) + e(t)
\]

In the formula: \(y(t) \in R^n\) and \(u(t) \in R^m\) are the input and output variables of the system; \(e(t) \in R^n\) is the additional noise of the system; where, \(k\) is the delay of the system.

\[
\begin{align*}
A(z^{-1}) &= 1 + A_1 z^{-1} + A_2 z^{-2} + \cdots + A_{n_s} z^{-n_s} \\
B(z^{-1}) &= 1 + B_1 z^{-1} + B_2 z^{-2} + \cdots + B_{n_s} z^{-n_s}
\end{align*}
\]

The above model is simply written as \(\text{CAR}(n,n-1)\) or \(\text{CAR}(n)\). Assuming that the system under consideration is open loop stability, the \(n, K, A, B\) in the system is unknown. This problem becomes based on the input and output data \(\{u(t), y(t), t = 1, 2, \ldots, N\}\) identification order \(n\), delay \(K\) and parameter matrix \(A_i(i = 1, 2, \ldots, n), B_i(i = 1, 2, \ldots, n-1)\).

Multi-variable economic system identification

\[
\begin{align*}
\theta_o &= \left[A_1, \ldots, A_{n_s}, B_1, \ldots, B_{n_s}\right]^T \\
B(t) &= \left[-y^T(t), y^T(t)\right]^T = \left[-y(t-1), \ldots, -y(t-A_{n_s}), u(t-1), \ldots, u(t-B_{n_s})\right]^T
\end{align*}
\]

The reference model can be written as a minimum multiplication format

\[
y(t) = \theta_o^T h(t) + e(t)
\]

In the equation, \(e(k)\) is colored noise and can be expressed as
\[ e(t) = A\left(y^{-1}\right)n(t) \]  

For convenience, consider the case of \( e(t) \).

Consider the following adjustable model

\[ y_m(t) = \frac{B\left(y^{-1}\right)}{A\left(y^{-1}\right)} e(t) \]

In the formula, \( e(t) \) and \( y_m(t) \) are the input and output variables of the adjustable model. Supposed

\[
\begin{align*}
\hat{\theta}(t) = & \left[ \hat{A}^T(t), \hat{B}^T(t) \right]^T = \left[ \hat{A}_1(t) \cdots \hat{A}_{n_a}(t), \hat{B}_1(t) \cdots \hat{B}_{n_b}(t) \right]^T \\
B(t) = & \left[ -\tau^T_m(t), u^T(t) \right]^T = \left[ -y_m(t-1), \cdots, -y_m(t-n_a), u(t-1), \cdots u(t-n_b) \right]^T
\end{align*}
\]

\[
\begin{align*}
y(t) = & \theta_0^T h(t) \\
y_m(t) = & \hat{\theta}(t) \hat{h}_m(t) = \left[ \hat{\theta}^T(t) + \hat{\theta}^p(t) \right]^T \hat{h}_m(t) \\
y_m^0(k) = & \left[ \hat{\theta}(t-1) \right]^T \hat{h}_m(t)
\end{align*}
\]

In the formula, \( \hat{\theta}(t) \) and \( \hat{\theta}^p(t) \) correspond to the integral and proportional operation outputs of the parameter adjustment mechanism, respectively.

3. Conditions of Multiple Variable Economic System Identification Model

In this paper, we use the F method to determine the rank of CAR model. The CAR(\( n \)) and CAR(\( n+1 \)) models have been established by the recursive least squares method, and the statistics are constructed.

\[
F' = \frac{S(n)-S(n+1)}{S(n+1)} \cdot \frac{m_{e} \cdot N - 2\times(n+1)\times m_{e} \times m}{2\times m_{e} \times m}
\]

\( F' \) obeys the F distribution and achieves a significant level of \( \lambda \), such as \( \lambda = 5\% \), which \( F \) is available from the \( F_\lambda \) distribution table.

If \( F' < F_\lambda \), CAR(\( n \)) is appropriate.

If \( F' \geq F_\lambda \), CAR(\( n \)) is not appropriate.

4. Validation of Multiple Variable Economic System Identification Model

Consider an economic system:

\[ y(t) = A_1 \cdot y(t-1) + B_0 \cdot u(t-1) + B_1 \cdot u(t-2) + e(t) \]
Assuming that $e(t)$ is zero mean and the variance matrix is $\text{diag}(0.025,0.025)$, the white noise. N=100 Calculation results:

If $F' < F_\lambda$, CAR(n) is appropriate.

\[
A_1 = \begin{bmatrix} 0.4 & -0.55 \\ -0.512 & 0.21 \end{bmatrix}, \quad B_0 = \begin{bmatrix} 0.21 & 1 \\ 0.25 & 0.21 \end{bmatrix}
\]

(11)

\[
B_1 = \begin{bmatrix} 0.51 & 0 \\ 0 & 0.51 \end{bmatrix}
\]

(12)

In this way, the identified model is

If $F' < F_\lambda$, CAR(n) is appropriate.

\[
\hat{A}_1 = \begin{bmatrix} -0.046 & -0.0071 \\ 0.0361 & 0.0124 \end{bmatrix}, \quad \hat{A}_2 = \begin{bmatrix} -0.046 & -0.0071 \\ 0.0361 & 0.0124 \end{bmatrix}
\]

(13)

\[
\hat{A}_3 = \begin{bmatrix} -0.0003 & 0.0065 \\ 0.0111 & -0.1164 \end{bmatrix}, \quad \hat{B}_0 = \begin{bmatrix} 0.2021 & 1.0051 \\ 0.2521 & 0.0124 \end{bmatrix}
\]

(14)

\[
\hat{B}_1 = \begin{bmatrix} 0.446 & -0.108 \\ 0.003 & 0.461 \end{bmatrix}, \quad \hat{B}_2 = \begin{bmatrix} -0.0392 & -0.077 \\ -0.0131 & 0.032 \end{bmatrix}
\]

(15)

In this way, the identified model is

\[
y(t) = \begin{bmatrix} 0.396 & -0.497 \\ -0.503 & 0.199 \end{bmatrix} y(t-1) + \begin{bmatrix} 0.2021 & 1.0051 \\ 0.2541 & 0.1951 \end{bmatrix} u(t-1)
\]

\[
+ \begin{bmatrix} 0.5 & 0 \\ 0 & 0.4911 \end{bmatrix} u(t-2)
\]

(18)

The identified model is basically the same as the real model.

This identification method can also be used for $n$ variable economic systems. In order to make the economic mathematical model describe the economic phenomenon more fundamentally, the identified model must satisfy certain economic theories such as consumption, investment, accumulation, and circulation.
5. Experiment simulation and analysis
MATLAB is used to identify the first-order model, second-order model, and third-order model of the multi-variable economic system. The specific identification process is as follows.

5.1. Simulation Example 1
Consider an economic system:

\begin{equation}
y(t) = A_1 \cdot y(t-1) + B_0 \cdot u(t-1) + B_1 \cdot u(t-2) + e(t)
\end{equation}

\begin{align*}
A_1 &= \begin{bmatrix} 0.4 & -0.55 \\ -0.512 & 0.21 \end{bmatrix}, & B_0 &= \begin{bmatrix} 0.21 & 1 \\ 0.25 & 0.21 \end{bmatrix} \\
B_1 &= \begin{bmatrix} 0.51 & 0 \\ 0 & 0.51 \end{bmatrix}
\end{align*}

Assuming that \( e(t) \) is zero mean and the variance matrix is \( \text{diag}(0.025, 0.025) \), the white noise. N=100 Calculation results:

(1) First-order model

\begin{align*}
\hat{A}_1 &= \begin{bmatrix} -0.481 & -0.0751 \\ 0.2361 & 0.4441 \end{bmatrix}, & \hat{B}_0 &= \begin{bmatrix} 0.3651 & 0.9691 \\ 0.2051 & 0.2781 \end{bmatrix}
\end{align*}

If \( F' < F_{\alpha} \), \( \text{CAR}(n) \) is appropriate.

The identified model is basically the same as the real model.

MATLAB is used to identify the multi-variable economic system identification model as a first-order model. The structure of the first-order model multi-variable economic system identification is shown in Figure 1:

It can be seen from Figure 1 that when the multi-variable economic system identification model is a first-order model, the identification of Economic Management Identification Curve and Original economic management input curve recognition are consistent, demonstrating that the method of this kind of multi-variable economic system identification is correct and meets the needs of economic development.
5.2. Simulation Example 2
Consider an economic system:

\[ y(t) = A_1 y(t-1) + B_0 u(t-1) + B_1 u(t-2) + e(t) \]  \hspace{1cm} (23)

\[ A_1 = \begin{bmatrix} 0.4 & -0.55 \\ -0.512 & 0.21 \end{bmatrix}, \quad B_0 = \begin{bmatrix} 0.21 & 1 \\ 0.25 & 0.21 \end{bmatrix}, \quad B_1 = \begin{bmatrix} 0.51 & 0 \\ 0 & 0.51 \end{bmatrix} \]  \hspace{1cm} (24) and (25)
Assuming that \( c(t) \) is zero mean and the variance matrix is \( \text{diag}(0.025, 0.025) \), the white noise. 
\[ N=100 \] Calculation results:

(2) Second-order model

\[
\hat{A}_1 = \begin{bmatrix} 0.40810 & -0.4751 \\ -0.4812 & 0.2301 \end{bmatrix}, \quad \hat{A}_2 = \begin{bmatrix} 0.001^* & 0.0014^* \\ 0.0041^* & 0.0119^* \end{bmatrix} \tag{26}
\]

\[
\hat{B}_0 = \begin{bmatrix} 0.2021 & 1.0051 \\ 0.2541 & 0.1951 \end{bmatrix}, \quad \hat{B}_1 = \begin{bmatrix} 0.4021 & -1.0171^* \\ -0.013^* & 0.4711 \end{bmatrix} \tag{27}
\]

If \( F' > F_{\alpha} \), CAR \( (n) \) is not appropriate.

![Figure 2. Economic Management Identification Curve Patterns 2.](image)

It can be seen from Figure 2 that when the multi-variable economic system identification model is a Second-order model, the identification of Economic Management Identification Curve and Original economic management input curve recognition are consistent, demonstrating that the method of this kind of multi-variable economic system identification is not correct and meets the needs of economic development.

5.3. Simulation Example 3

Consider an economic system:

\[
y(t) = A_1 \cdot y(t-1) + \hat{B}_0 \cdot u(t-1) + \hat{B}_1 \cdot u(t-2) + e(t) \tag{28}
\]

\[
A_1 = \begin{bmatrix} 0.4 & -0.55 \\ -0.512 & 0.21 \end{bmatrix}, \quad B_0 = \begin{bmatrix} 0.21 & 1 \\ 0.25 & 0.21 \end{bmatrix} \tag{29}
\]
Assuming that $\epsilon(t)$ is zero mean and the variance matrix is $\text{diag}(0.025, 0.025)$, the white noise.

N=100 Calculation results:

(3) Third-Order model

$$
\hat{A}_1 = \begin{bmatrix}
0.4741 & -0.3441 \\
-0.4361 & 0.1641 \\
0.0111 & -0.1164
\end{bmatrix}, \quad \hat{A}_2 = \begin{bmatrix}
-0.046 & -0.0071 \\
0.0361 & 0.0124
\end{bmatrix}
$$

$$
\hat{A}_3 = \begin{bmatrix}
-0.0003 & 0.0065 \\
0.0111 & -0.1164
\end{bmatrix}, \quad \hat{B}_0 = \begin{bmatrix}
0.2021 & 1.0051 \\
0.2521 & 0.0124
\end{bmatrix}
$$

$$
\hat{B}_1 = \begin{bmatrix}
0.446 & -0.108 \\
0.003 & 0.461
\end{bmatrix}, \quad \hat{B}_2 = \begin{bmatrix}
-0.0392 & -0.077 \\
-0.0131 & 0.032
\end{bmatrix}
$$

If $F' < F_k$, CAR(n) is appropriate.

![Economic Management Identification Curve Patterns 3.](image)

It can be seen from Figure 3 that when the multi-variable economic system identification model is a Third-Order model, the identification of Economic Management Identification Curve and Original economic management input curve recognition are consistent, demonstrating that the method of this kind of multi-variable economic system identification is correct and meets the needs of economic development.

6. Summary

(1) This identification method can also be used for n variable economic systems.
In order to make the economic mathematical model describe the economic phenomenon more fundamentally, the identified model must satisfy certain economic theories such as consumption, investment, accumulation, and circulation.

(2) Using MATLAB to identify the multi-variable economic system identification model, the simulation results show that the recognition Economic Management Identification Curve and Original economic management input curve recognition are consistent, demonstrating that the method of identifying the multi-variable economic system is correct and meets the needs of economic development. It has a strong reference value.

Acknowledgements
The authors thank the financial supports from National Natural Science Foundation of China (Grant no. 51165024) and Science and Technology Major Project of “High-grade NC Machine Tools and Basic Manufacturing Equipment” (2010ZX040001-181).

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