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Multivariate linear regression analysis on online image study for IoT

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Abstract

To improve the effectiveness of national image study on the "Belt and Road" countries in Central Asia, a national image study method based on the multivariate linear is proposed in this paper. First, the national competitiveness database of International Institute for Management Development (IMD) and World Economic Forum is adopted to construct the evaluation index system of the "Belt and Road" countries; second, the multivariate linear regression analysis method is introduced to analyze the evaluation index system model of the "Belt and Road" countries mentioned above; third, the effectiveness of the proposed algorithm is verified through the simulation experiment.

Keywords: Central Asian countries; The Belt and Road; National image; Multivariate linear regression; Index system

1. Introduction

The "Belt and Road" proposed by China is an important development strategy designed on the basis of coordinating the domestic and international economic development in line with the principle of mutual benefit to bring benefits to people in countries along the route. The strategy is of important significance to build the new external development pattern, improve the Chinese economic development level rapidly and achieve the great rejuvenation. Also, the "Belt and Road" key development strategy has played a promoting role in providing opportunities for the development of special language disciplines at colleges and universities (Christenson et al., 2015; Goodsitt et al., 2014; Iidaka, Anderson, Kapur, Cabez, & Craik, 2014; Lawler et al., 2014; Yamasaki et al., 2015).

In the "Belt and Road" key development strategy, interconnection and intercommunication is the basic requirement of this strategic development and main goal of the "Belt and Road" development strategy. It's a huge system engineering to realize the interconnection and intercommunication, in which, the language intercommunication is the foundation and premise that plays an important role in non-governmental exchange, trade communication, facility construction and policy coordination etc. There are 65 countries along the "Belt and Road" development strategy involving 65 languages, among which most are the special languages. However, the domestic colleges and universities fall far behind the requirement of the "Belt and Road" strategy development in cultivating the talents in special language; the talent resources are scarce. According to statistics, only about 20 special languages are available in mainland China, among which most are centralized in one college. Under this educational background, it fails to match with the requirements of the "Belt and Road" strategy development. Talents in the special language generally become the indispensable resources for the national strategic development (Jørgensen et al., 2014; Raza & Khosravi, 2015; Tsai, Lai, & Vasilakos, 2014; Xu, Yang, Yang, & Lei, 2014; Yan, Ricci, Subramanian, Liu, & Sebe, 2014).

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In the "Belt and Road" key development strategy, without language fusion in advance (Feng, Hu, Chen, & Song, 2014; Groenendijk, Sass-Klaassen, Bongers, & Zuidema, 2014; Ingraffea, Wells, Santoro, & Shonkoff, 2014; Toporcov et al., 2015), it will be difficult to make the cultural exchange and communication, not mention the economic and non-governmental exchange; also, the effect of interconnection and intercommunication will be discounted greatly. In the meantime, without language communication, the governmental communication is unavailable while the development of international trade, accommodation of funds will be influenced as well (Ashokkumar, Arunkumar, & Don, 2018; Hussein, ArunKumar, et al., 2018; Hussein, Kumar, et al., 2018; Khanna et al., 2018; Wei, Meng, & Arunkumar, 2018). Therefore, to implement the "Belt and Road" key development strategy, the cultivation of talents in special language must be put on the agenda to strengthen the construction of relate courses at colleges and universities, which need to be pushed gradually due to the greater difficulties according to the current development (Abdulhay, Elamaran, Arunkumar, & Venkatraman, 2018; Abdulhay, Arunkumar, Narasimhan, Vellaiappan, & Venkatraman, 2018; Elhoseny et al., 2018; Sarvaghad-Moghaddam et al., 2018; Tharwat, Elhoseny, Hassanien, Gabel, & Arunkumar, 2018; Vardhana, Arunkumar, Abdulhay, & Ramirez-Gonzalez, 2018).

2. Model description

The international competitiveness database of IMD and WFF in 1995 is adopted in this paper, data from 2007 to 2012 are selected to analyze the soft index national image (image abroad). This database contains 59 countries with 206 hard indexes and 117 soft indexes. In this paper, the research results of Li Wangyue et al. are consulted; 11 of all indexes are selected to interpret the national image as shown in Table 1 from the perspective of relativity and regression results after considering the missing values in the database. In Table 1, (T) means that the more suitable it is to the condition, the higher the index score; i.e., in the urbanization indexes, the more supportive the cities to the business development in the country, the higher its urbanization index score, otherwise, the lower it is.

3. Multivariate regression analysis

The theory of multivariate regression analysis is the same with that of the univariate linear regression analysis only with the free variable being extended from unitary into multivariate; therefore, the calculation will be relatively complicate. The multivariate linear regression analysis will be briefly introduced now.

3.1. Building of mathematical model

Assume there is the following relationship between the variable y and $x_1, x_2, \ldots, x_m$:

$$\begin{aligned} y &= \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_m x_m + \varepsilon \\ &\quad \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_m x_m \end{aligned} \tag{1}$$

In which, y is the random variable, $x_1, x_2, \ldots, x_m$ is the nonrandom variable and $\beta_1, \beta_2, \ldots, \beta_m$ is called the regression coefficient. ε is the random variable as the random error, it can be understood as the error caused by other various random factors that cannot be interpreted by $x_1, x_2, \ldots, x_m$ in y. We must adopt $\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_m x_m$ to estimate the mean value $E(y)$ of y, which means

$$E(y) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_m x_m.$$

Assume that $\varepsilon \sim N(0, \sigma^2)$, $y \sim N(\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_m x_m, \sigma^2)$, $\beta_0, \beta_1, \ldots, \beta_m$, σ^2 are the undetermined constants unrelated to $x_1, x_2, \ldots, x_m$.

To estimate $\beta_i (i = 0, 1, 2, \ldots, m)$, n independent tests (or observations) are made on variable $(x_1, x_2, \ldots, x_m, y)$ to obtain n groups of independent observation data as:

$$(x_{i1}, x_{i2}, \ldots, x_{im}, y_i), \quad i = 1, 2, \ldots, n. \tag{2}$$

On the other hand, the n groups of independent observation data $(x_{i1}, x_{i2}, \ldots, x_{im}, y_i)(i = 1, 2, \ldots, n)$ of variable $(x_1, x_2, \ldots, x_m, y)$ shall meet:

Table 1
Factors influencing the national image.

	Index category	Index name and connation
Soft index	Economic development	1. Urbanization: the city supports the business development; the city doesn't support the business development
		2. Economic recovery capacity: strong or slow
		3. Employment relationship: the relationship between the managers and employees is efficient or hostile
	Government administration	4. Risk of political instability: very low or high
		5. Human and property safety: confident or not confident about the human and property safety being protected
Soft index	Financial efficiency	6. Difficulty level of entering the domestic and foreign capital markets: very easy or not easy
	Trade liberalization	7. Attitude to globalization: positive or negative in your homeland
Hard index	Government administration	8. Proportion of the central government expenditure in GDP
	Financial construction	9. National credit rating: percentile rating according to the assessment in the magazine Institutional Investor
	Educational level	10. Humanity development index:composite index of economy, society and education
	Population structure	11. Proportion of population above 65 years old in the total population (%)

$$\begin{cases} y_1 = \beta_0 + \beta_1 x_{11} + \beta_2 x_{12} + \cdots + \beta_m x_{1m} + \varepsilon_1, \\ y_2 = \beta_0 + \beta_1 x_{21} + \beta_2 x_{22} + \cdots + \beta_m x_{2m} + \varepsilon_2, \\ \cdots\cdots \\ y_n = \beta_0 + \beta_1 x_{n1} + \beta_2 x_{n2} + \cdots + \beta_m x_{nm} + \varepsilon_n. \end{cases} \tag{3}$$

In which $\beta_0, \beta_1, \ldots, \beta_m$ are the parameters to be estimated, $\varepsilon_1, \varepsilon_2, \ldots, \varepsilon_n$ are n random variables independent from each other and obeying the normal distribution $N(0, \sigma^2)$; formula is called the mathematical model of multivariate linear regression.

If there is

$$X = \begin{pmatrix} 1 & x_{11} & x_{12} & \cdots & x_{1m} \\ 1 & x_{21} & x_{22} & \cdots & x_{2m} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & x_{n1} & x_{n2} & \cdots & x_{nm} \end{pmatrix}, \quad Y = \begin{pmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{pmatrix},$$

$$\beta = \begin{pmatrix} \beta_0 \\ \beta_1 \\ \vdots \\ \beta_m \end{pmatrix}, \quad \varepsilon = \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_n \end{pmatrix}.$$

Then the matrix pattern of formula (21) will be:

$$Y = X\beta + \varepsilon. \tag{4}$$

3.2. Least square estimation of parameters

Like the theory of the univariate linear regression, with the principle of minimizing the error sum of squares

$$\sum_{i=1}^{n} \varepsilon_i^2$$

is adopted to estimate the parameters $\beta_0, \beta_1, \ldots, \beta_m$ of the theoretical regression equation

$$E(y) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_m x_m \tag{5}$$

As

$$Q(\beta_0, \beta_1, \ldots, \beta_m) = \sum_{i=1}^{n} \varepsilon_i^2 = \sum_{i=1}^{n} (y_i - \beta_0 - \beta_1 x_{i1} - \cdots - \beta_m x_{im})^2,$$

The estimated values $\hat{\beta}_0, \hat{\beta}_1, \ldots, \hat{\beta}_m$ of $\beta_0, \beta_1, \ldots, \beta_m$ shall be the solution to the equations system:

$$\begin{cases} \frac{\partial Q(\beta_0, \beta_1, \ldots, \beta_m)}{\partial \beta_0} = 0, \\ \frac{\partial Q(\beta_0, \beta_1, \ldots, \beta_m)}{\partial \beta_t} = 0, \quad t = 1, 2, \ldots, m \end{cases} \tag{6}$$

The equation group (6) is the normal equations system with unique solution. The matrix pattern of equations system (24) shall be:

$$(X^T X)\beta = X^T Y.$$

If the estimated values of parameters $\beta_0, \beta_1, \ldots, \beta_m$ to be estimated in regression equation (5) are

$$\hat{\beta} = (\hat{\beta}_0, \hat{\beta}_1, \ldots, \hat{\beta}_m)^T.$$

Then

$$\hat{\beta} = (X^T X)^{-1} X^T Y. \tag{7}$$

The solved equation will be

$$\hat{y} = \hat{\beta}_0 + \hat{\beta}_1 x_1 + \hat{\beta}_2 x_2 + \cdots + \hat{\beta}_m x_m. \tag{8}$$

And equations system (6) can be written as

$$\begin{cases} s_{11}\beta_1 + s_{12}\beta_2 + \cdots + s_{1m}\beta_m = s_{1y}, \\ s_{21}\beta_1 + s_{22}\beta_2 + \cdots + s_{2m}\beta_m = s_{2y}, \\ \cdots\cdots \\ s_{m1}\beta_1 + s_{m2}\beta_2 + \cdots + s_{mm}\beta_m = s_{my}. \end{cases} \tag{9}$$

In which

$$s_{ij} = \sum_{k=1}^{n} (x_{ki} - \bar{x}_i)(x_{kj} - \bar{x}_j), i, j = 1, 2, \ldots, m;$$

$$\bar{x}_i = \frac{1}{n} \sum_{k=1}^{n} x_{ki}, i = 1, 2, \ldots, m;$$

$$s_{iy} = \sum_{k=1}^{n} (x_{ki} - \bar{x}_i)(y_k - \bar{y}), i = 1, 2, \ldots, m; \quad \bar{y} = \frac{1}{n} \sum_{k=1}^{n} y_k.$$

If

$$S = (s_{ij})_{m \times m}, \quad C = (c_{ij})_{m \times m} = S^{-1}, \quad S_y = (s_{1y}, s_{2y}, \ldots, s_{my})^T \tag{10}$$

Then

$$(\hat{\beta}_1, \hat{\beta}_2, \cdots, \hat{\beta}_m)^T = S^{-1} S_y = C S_y, \quad \hat{\beta}_0 = \bar{y} - \hat{\beta}_1 \bar{x}_1 - \hat{\beta}_2 \bar{x}_2 - \cdots - \hat{\beta}_m \bar{x}_m.$$

3.3. Significance test of regression equation

(1) Decomposition of total sum of deviation squares

$$L_{yy} = \sum_{k=1}^{n} (y_k - \bar{y})^2 = \sum_{k=1}^{n} (y_k - \hat{y}_k)^2 + \sum_{k=1}^{n} (\hat{y}_k - \bar{y})^2,$$

In which,

$$\hat{y}_k = \hat{\beta}_0 + \hat{\beta}_1 x_{k1} + \hat{\beta}_2 x_{k2} + \cdots + \hat{\beta}_m x_{km} (k = 1, 2, \ldots, n),$$

is called the theoretical value and the mean value of which is $\bar{y}$.

If

$$U = \sum_{k=1}^{n} (\hat{y}_k - \bar{y})^2, \quad Q = \sum_{k=1}^{n} (y_k - \hat{y}_k)^2.$$

Then U is called the regression sum of square that reflects the fluctuations of $y_k (k = 1, 2, \ldots, n)$ caused by the variations of independent variable, its free degree is m (for the number of independent variables is m); Q is called the residual sum of square that reflects the influences of fluctuations of any other random factors (including the experimental error); its free degree is the free degree of L_{yy} minus m, namely $(n-1) - m = n - m - 1$.

(2) Significance test

The significance test of regression equation refers to the test of the assumption

$$H_0 : \beta_1 = \beta_2 = \cdots = \beta_m = 0. \tag{11}$$

To testify that

$\frac{Q}{\sigma^2} \sim x^2(n-m-1)$, U and Q are mutually independent.

When assumption H_0 is established, we can testify that

$$\frac{U}{\sigma^2} \sim x^2(m)$$

Therefore, according to the definition of Fdistribution, upon the conditions of H_0 is established,

$$F = \frac{U/m}{Q/(n-m-1)} \sim F(m, n-m-1). \tag{12}$$

With the test statistic F, under the given significance level α, the rejection region of assumption H_0 is:

$$F > F_\alpha(m, n-m-1).$$

If assumption H_0 is not rejected, the regression effect of Eq. (8) will be insignificant, which means there is not significant linear statistical relation between the variable y and $x_1, x_2, \ldots, x_m$, the regression equation (8) has no actual significance; it means there is significant linear statistical relation between the variable y and $x_1, x_2, \ldots, x_m$.

4. Empirical analysis

In this paper, the factors influencing the national image are studied by the R software through quantile regression and ordinary least square regression to discover the influential variables according to the significance of regression result. To state the result more clearly, coefficients of various variables in the quantile regression equations at 5%, 25%, 50%, 75% and 95% are listed in Table 1 while the result of ordinary least square regression is listed on the side for comparison. As the nodal increment is not the factor influencing the national image investigated in this paper, the summary chart (Fig. 1) has more intuitive results and reflects more information. Among the confidence belts about coefficient obtained below, there contains the location and scale variation information about the independent variable distribution. Take the "risk of political instability" (x137) as an example, the coefficient estimations at all quantile points are represented by the black points while the grey belt refers to 95% of the confident belt. Make a comprehensive summary of the scales of the longitudinal coordinate, it can be seen that the confident belts of the coefficient estimations are above 0 (in other diagrams, the 0 location is represented by a horizontal wide grey line). It means that with other conditions unchanged, the coefficient improvement will bring forth positive influences on the national image; also, as the confident belts are all above 0, the coefficients are significant on all quantile points (which is reflected in this table). On the other hand, the

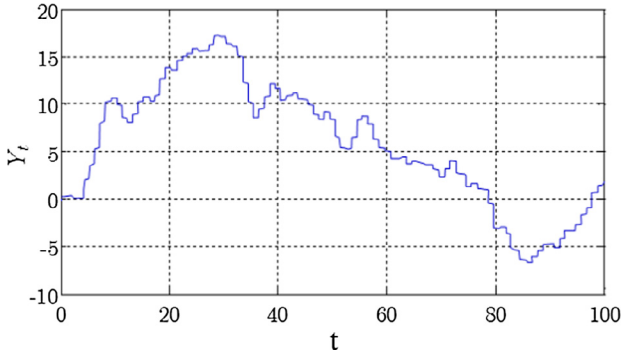

Fig. 1. Summary chart of the quantile regression results.

confident belts of "difficulty level of entering the domestic capital market" (x118) are at about 0.4 quantile point through the 0 line; therefore, it is only significant in the coefficient estimation of the first half and only the coefficient at the 25% quantile point is significant.

Also, if the coefficient estimation is almost horizontal, such as the "attitude to globalization" (x205), has reflected that the variable only changes the location of conditional distribution, namely the positive influence on the figure. For the "difficulty level of entering the domestic and foreign capital markets" (x118), the coefficient estimation is downward sloping, in other words, the coefficient estimation is decreased as the quantile point is increased. It not only changes the conditional distribution on location, but also influences the shape of conditional distribution, which means the conditional distribution of national image is leftward. Generally speaking, coefficients of "difficulty level of entering the domestic and foreign capital markets" (x118), economic recovery capacity (x18) and proportion of population above 65 years old in the total population (%) (x220) will be greatly increased or decreased as the quantile points are increased. According to the rather level or undetermined trend of the coefficient estimation lines of other variables, variables except for the above three influence the conditional distribution of national image on location. As the fluctuation amplitudes of the longitude coordinates are not uniformed, the variations of the confident belt widths of the coefficient estimation among figures cannot be compared directly. In case the confident belts of a variable fluctuate around 0, the coefficients of this variable will be insignificant at all quantile points. As the confident belts of influencing variables selected in this paper are basically on one side of the 0 line, there will be determined influences on the national image, which has testified the reasonability of the variables selected in this paper from one side. According to the previous analysis, only the coefficients of some variables change clearly along with the quantile points, so that it is appropriate to explain the influences of most variables from location. It also indicates that the influences on national image are rather coincident on all quantile points. There is the explanation according to the different variables based on the real significance.

5. Conclusion

According to the previous analysis results it can be seen that "risk of political instability", "proportion of the central government expenditure in GDP" and humanity development index are the largest factors influencing the national image; "proportion of population above 65 years old in the total population" and "economic recovery capacity" have local important influence on the national image. In combination with the classification of the information reflected by the variables, the governmental administration level and educational level have key influence on the national image at all levels; also, the population structure and economic development are the relatively secondary factors influencing the national image. As a developing country, China shall improve the governmental administration level, increase the attention to social issues i.e. education and population at the same time of focusing on economic development and financial construction.

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