

AN APPLICATION OF THE CANONICAL CORRELATION

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Abstract : *the paper deals with an experimental application of the canonical correlation in the study of the social environment in the last year Romania . To do this , two groups of variables are selected : one group representing the social effort and the other the social effect of the labour.*

There studied the characteristic of the dependence between them. The conclusion is that – in the considered period – the greater was the effort, the smaller was the effect . Two different variants of the canonical correlation method were used to prove this Both of them confirm this conclusion.

Keywords: canonical correlation ; canonical variates; the COREMAX method
multivariate analysis

The aim of the classical canonical correlation analysis is studying relationships between sets of multiple dependent and multiple independent variables.

So, let X be a p – dimensional and Y be a q – dimensional random variable .

We look for two vectors a , b such that $a \in \mathbf{R}^p$, $b \in \mathbf{R}^q$ and the quadratic KENDALL correlation coefficient $\text{correl}^2 (a \cdot X, b \cdot Y)$ be maximal.

Note that the univariate random variable $U = a \cdot X$ and $V = b \cdot Y$ are known as *the canonical variates* of the variables X , resp. Y , and that a , b are the corresponding *canonical coefficients* .

This problem was solved long before (from **Harold Hotelling** -1939 to **Joseph F. Hair** ,1998 for example).

In this paper the canonical correlation method will be applied to study dependence between the group

$X = \{ \text{civil employment ; employment rate} \}$

as the group of independent variables , and

$Y = \{ \text{average net nominal monthly earnings ; total expenditure of household} \}$

as the group of independent variables.

The data in our study are the next (<http://www.insse.ro/cms/files/pdf/en/cp3.pdf>)

Year	X1	X2	Y1	Y2
1997	11050	60.9	63.1	138.58*
1998	10845	59.6	104	196.31*
1999	10776	63.5	152	274.21*
2000	10508	63.6	214	375.92*
2001	10440	62.9	302	516.52
2002	9234	58	379	651.66
2003	9223	57.8	484	781.45

2004	9158	57.9	599	1049.44
2005	9147	57.7	746	1149.33

Here , as stated above :

$X_1 = \text{civil employment}$
 $X_2 = \text{employment rate}$
 $Y_1 = \text{average net nominal monthly earnings}$
 $Y_2 = \text{total expenditure of household .}$

(The stated data are author's estimations).

First there proceeds to normalize this data ,in order to obtain a less error level (as is well known, the

normalized variable \hat{V} that corresponds to the variable V , is given by

$$\hat{V} = \frac{V - E(V)}{\sigma(V)},$$

where $E(V)$ is the expected value ,and $\sigma(V)$ - the standard deviation of the variable V).

The normalized variables are then represented by the next table :

Year	\hat{X}_1	\hat{X}_2	\hat{Y}_1	\hat{Y}_2
1997	1.217	0.268	-1.174	-1.180
1998	0.970	-0.238	-0.999	-1.023
1999	0.886	1.281	-0.794	-0.810
2000	0.563	1.320	-0.530	-0.532
2001	0.480	1.047	-0.154	-0.147
2002	-0.977	-0.861	0.174	0.222
2003	-0.990	-0.939	0.623	0.577
2004	-1.068	-0.900	1.113	1.310
2005	-1.082	-0.978	1.741	1.583

The estimated total correlation matrix of this last dataset is then :

$$S = \begin{pmatrix} S_{XX} & S_{XY} \\ S_{YX} & S_{YY} \end{pmatrix}, \text{ with :}$$

$$S_{XX} = \begin{pmatrix} 1 & 0,7834 \\ 0,7834 & 1 \end{pmatrix}; \quad S_{XY} = \begin{pmatrix} -0,9167 & -0,9268 \\ -0,6744 & -0,6783 \end{pmatrix}$$

$$S_{YX} = \begin{pmatrix} -0,9167 & -0,6744 \\ -0,9268 & -0,6783 \end{pmatrix}; \quad S_{YY} = \begin{pmatrix} 1 & 0,9957 \\ 0,9957 & 1 \end{pmatrix}$$

There determines now the largest eigenvalues of the matrices

$$\mathbf{A} = (\mathbf{S}_{XX})^{-1} \cdot \mathbf{S}_{XY} \cdot (\mathbf{S}_{YY})^{-1} \cdot \mathbf{S}_{YX} = \begin{pmatrix} 0,9586 & 0,6959 \\ -0,1216 & -0,0850 \end{pmatrix}$$

and

$$\mathbf{B} = (\mathbf{S}_{YY})^{-1} \cdot \mathbf{S}_{YX} \cdot (\mathbf{S}_{XX})^{-1} \cdot \mathbf{S}_{XY} = \begin{pmatrix} -0,7034 & -0,7152 \\ 1,5554 & 1,5770 \end{pmatrix}$$

The (common) largest eigenvalue of the matrices **A**, **B** is $\lambda = 0,87$.

This is equally the quadratic measure of dependence between the two groups ,
{ X₁,X₂ } and **{ Y₁,Y₂ }** (details will be seen later).

The canonical coefficients are the eigenvectors , corresponding to $\lambda = 0,87$: there obtain

$$\mathbf{a} = (0,992 ; - 0,1263) , \mathbf{b} = (- 0,4138 ; 0,9104)$$

therefore

$$\mathbf{U} = 0,992 \cdot \mathbf{X}_1 - 0,1263 \cdot \mathbf{X}_2 ; \mathbf{V} = - 0,4138 \cdot \mathbf{Y}_1 + 0,9104 \cdot \mathbf{Y}_2 .$$

U	V
1.17382	-0.5893
0.99194	-0.5178
0.71784	-0.4087
0.39175	-0.2649
0.34461	-0.0703
-0.8602	0.13015
-0.8636	0.26788
-0.9464	0.73189
-0.9498	0.72111

If compute now the correlation coefficient **correl (U,V)** , there obtains

$$\mathbf{correl (U,V)} = - 0,93285 ;$$

obviously , $[\mathbf{correl (U, V)}]^2 = \lambda$.

For **correl (U,V) < 0** , there results that the dependence of **{ Y₁,Y₂ }** with respect to
{ X₁,X₂ } is of negative type : the greater **{ X₁,X₂ }** become , the poor **{ Y₁,Y₂ }** become.

Otherwise, **correl (U,V)** being so near of -1 , the dependence is strong enough to let us consider the group
{ X₁,X₂ } determinative for **{ Y₁,Y₂ }**.

The values of the canonical variates are processed below :

$\tilde{\mathbf{X}}_1$	$\tilde{\mathbf{X}}_2$	$\tilde{\mathbf{Y}}_1$	$\tilde{\mathbf{Y}}_2$
1	0.542	0	0
0.892	0.322	0.060	0.057

0.856	0.983	0.130	0.134
0.715	1.000	0.221	0.235
0.679	0.881	0.350	0.374
0.046	0.051	0.463	0.508
0.040	0.017	0.616	0.636
0.006	0.034	0.785	0.901
0	0.000	1	1

A reason the canonical correlation method is not used so widely is that the practical meaning of the canonical coefficients is rarely clear.

To remediate that, different versions of the method are improved.

One of them is the **COREMAX** method (see (2)), that gives the coefficients the meaning of *degrees of contributions* of each component of the group to the corresponding canonical variate.

To do this, we'll denote:

$$\eta = \alpha \cdot X_1 + (1 - \alpha) \cdot X_2; \quad 0 \leq \alpha \leq 1$$

$$\mu = \beta \cdot Y_1 + (1 - \beta) \cdot Y_2; \quad 0 \leq \beta \leq 1$$

Now, we look for values α , β that maximize $\text{correl}(\eta, \mu)$.

To make economic interpretation possible, we'll enforce to the variables another kind of being comparable, instead of normalization: thus, the *normed variables* are more adequate. This is justified by the fact that negative values of the variables are equally difficult to interpret; or, the normalization unavoidable gives negative values to normalized variables.

Remind that, for a variable series V , the normed series \tilde{V} is given by

\tilde{X}_1	\tilde{X}_2	\tilde{Y}_1	\tilde{Y}_2
1	0.542	0	0
0.892	0.322	0.060	0.057
0.856	0.983	0.130	0.134
0.715	1.000	0.221	0.235
0.679	0.881	0.350	0.374
0.046	0.051	0.463	0.508
0.040	0.017	0.616	0.636
0.006	0.034	0.785	0.901
0	0.000	1	1

$$\tilde{V} = \frac{V - \min\{V\}}{\max\{V\} - \min\{V\}}.$$

There obtains :

Applying technique described in (2) , there obtains

$$\alpha = 0,47 ; \beta = 0,70 ; \max \text{Correl}(\mu ; \eta) = - 0,8376$$

this value being close enough to $\max \text{correl} (U,V) = - 0,93285$.

Finally : in the next ,

- the canonical variate $\mu = 0,47 \cdot X_1 + 0,53 \cdot X_2$ gets the name of “synthetical employment”
- the canonical variate $\eta = 0,7 \cdot Y_1 + 0,3 \cdot Y_2$ gets the name of “synthetical earning”

Then: - the synthetical earning depends strongly from the synthetical employment ;

- the intensity of this dependence is about 83,76%
- the dependence is of the negative type : the greater the synthetical employment , the smaller the synthetical earning becomes .

In other words : in the mentioned period , the greater was the effort,
the smaller was the effect .

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