Scientific Annals of Economics and Business
63 (2), 2016, 225-235
DOI: 10.1515/aicue-2016-0018

INFORMATION CHANNELS EFFECTIVENESS ASSESSMENT ON THE BASIS OF DATA FROM STATISTICAL SURVEY

Milan TEREK*

Abstract

The paper deals with the possibilities of using the data from statistical survey for information channels effectiveness assessment in the case when the same information is provided by more different information channels to different groups of people in the framework of one time period. The association between two categorical variables is analyzed. Values of the first variable represent information channels and values of second one represent different groups of people obtaining information through these information channels. The procedure of information channels effectiveness assessment for different groups of people is suggested. The proposed procedure is applied in information flows about academic ethics improvement at one Slovak university.

Keywords: information channels, association between two categorical variables, adjusted standardized residuals, odds ratio, academic ethics

JEL classification: C46, M12

1. INTRODUCTION

In the paper will be shown how to use the data from statistical survey for information channels effectiveness assessment in case when the same information is provided by more different information channels to different groups of people in the framework of one time period. Some methods of association between two categorical variables[1] analysis will be applied in that assessment.

Frequently the same information in the framework of one time period is provided by more different information channels. For example a firm informs the people about offered services by paper publicity materials, internet and publicity in media. It is interested in the effectiveness of the information channels for the potential clients from different regions. The council of town informs the citizens about its activities by the network of billboards, its web page and communal media. It would like to know the effectiveness of information channels for different age categories of citizens. Natural first step of such analysis is asking the people what information channel from they obtain or obviously obtain the information – to

* Faculty of Economic Informatics, University of Economics, Slovakia; e-mail: *milan.terek1@gmail.com.*

realize statistical survey. The questions concerning information channels using and different groups of people are generally categorical variables. The association between two categorical variables will be analyzed – categories of the first variable represent information channels and categories of second one represent different groups of people obtaining information through these information channels. When results of one variable tend to change as the results of the other variable take different values, we conclude there exists an association between those variables. Data for categorical variables association analysis are summarized in contingency tables.

The procedure of information channels effectiveness assessment for different groups of people will be suggested. The using of proposed procedure of information channels effectiveness assessment will be illustrated on the problem of information flows about academic ethics improvement at School of Management in Trenčín/City University of Seattle (VŠM /CU). The goal of the survey was to gather the information about information flows – to find how the students are informed about academic ethics issues, whether they consider the current way of application of academic ethics rules as effective, to what extent the level of academic ethics awareness differs among diverse groups of students and so on[2]. The obtained information provides the basis for improving information flows about academic ethics. Ensuring efficient information flows about academic ethics should increase the level of academic ethics awareness among students and teachers and so improve the quality of education at VŠM/CU.

2. MATERIAL AND METHODS

In Zeng *et al.*, n.d., the managing information flows for quality improvement in construction are analyzed. The reengineering of current management strategy for establishing an effective information network for quality management is proposed. In the paper Demski *et al.*, 1999 an analysis how bureaucracies are erected within the firm to control information flows and protect clients is realized. In Sousa, 2010S key ecosystem characteristics, adaptation, emerges as the key factor for dynamical development of information system architecture. The paper Xiaohui Liu and Youwang Sun, 2011 analyzes information flow management of information system in automobile parts inbound logistics based on the environment of internet of things. Bauereiß and Hutter, 2014 in their paper focuses on information flow control, taking into account implicit information leaks. The presented approach operates on a specification level in which no executable program is available yet. The authors illustrate the modeling of a work flow management system as a composition of state-event systems, each representing one of the activities of the workflow. The paper Bhargav *et al.*, 2010 focuses on improving information flow within the production management system with web services. In Peng Li and Zdancewic, 2005 the security of web-scripting languages is analyzed and the scripting language uses principles based on the well-studied techniques in information-flow type systems is described.

The specific problem of using more information channels for providing the same information in the framework of one time period and their effectiveness assessment for different groups of people is not studied in the cited works. We will show how to solve this problem with aid of association between two categorical variables analysis.

2.1. The Used Methods

Commonly three procedures of association analysis between two categorical variables are advised in the literature. The first consists of two steps – the realization of the test revealing if the association between variables exists and if that is the case, the measurement how strong is the existing association with aid of some summary measures of association, such as Cramer`s *V*, contingency coefficient or Goodman and Kruskal's lambda[3] (advised for example in Miller and Miller, 2004; Dagnelie, 1998). The second procedure includes the testing of association and the using of adjusted standardized residuals[4] enabling the study of the structure of association when the association was confirmed (for example Sharpe *et al.*, 2010). The adjusted standardized residuals serve for identification cells of contingency table which are "responsible" for revealed association. The last procedure consists of association testing, the using of adjusted standardized residuals in the case of confirmed association and the measurement of the strength of association by odds ratios (for example in Agresti and Finlay, 2014). It will be shown in the paper that for information channels effectiveness assessment in the stated context, the last mentioned procedure will be useful.

2.1.1. The association testing

The r x c ($c > 2$) contingency table will be analyzed. When both categorical variables are nominal, the Pearson chi-squared test[5] is used for association testing. In the case when random samples from r multinomial populations with c different outcomes are sampled, the test calls the test of homogeneity. When one sample from multinomial population with rc different outcomes is sampled, the independence is tested and the test calls the test of independence. The testing procedures are the same in both cases. Many well-known statistical methods for categorical data treat all response variables as nominal. That is, the results are invariant to permutations of the categories of those variables, so they not utilize the ordering if there is one. Example is the Pearson chi-squared test of independence or homogeneity. Test statistics and *P*-values take the same values regardless of the order in which categories are listed. Some researchers routinely apply such methods to nominal and ordinal variables alike because they are both categorical. The ordinality of variables is simply ignored. An ordinal analysis can give quite different and much more powerful results than an analysis that ignores the ordinality.

When both variables are ordinal, two types of association between variables can be discussed – a positive one and a negative one. When positively associated, a subject with a higher value of one variable tends to bear a higher value of the second variable and a subject with a lower value of one variable tends to bear a lower value of the second variable. When negatively associated, a subject with a higher value of one variable tends to bear a lower value of the second variable and a subject with a lower value of one variable tends to bear a higher value of the second variable. The test of association can be based on some ordinal measure such as gamma[6]. A test of independence based on an ordinal measure is usually preferred to the chi-squared test when the both variables are ordinal. The χ^2 statistic ignores the ordering of the categories, taking the same value no matter how the levels are ordered. If positive or negative trend exists, ordinal measures are usually more powerful for detecting it. When the dependence does not have an overall positive or negative trend, the chi-squared test can perform better than the ordinal test (Agresti and Finlay, 2014, pp. 244-245). An alternative

approach to association analysis of contingency tables containing two ordinal variables lies in assigning scores to variable values. Then, it is possible to analyze the variables as quantitative.

In the analyses of contingency tables containing one nominal variable having two values and one ordinal variable, the resulting mathematical sign of the measure indicates which value of nominal variable is bonded to a higher value of ordinal variable and described procedures are valid. In case of the nominal variable having more than two values the assigning scores to the values of ordinal variable and then application of analysis of variance is recommended.

2.1.2. Residual Analysis

A cell-by-cell comparison of the observed and expected frequencies reveals the nature of the evidence about the association between variables. Let n_{ij} be the observed frequency in the *i*-th row and *j*-th column of contingency table, $n_{i.}$ be the sum of n_{ij} values in the *i*-th row, $n_{.j}$ be the sum of n_{ij} values in the *j*-th column. The sum of all n_{ij} values is sample size *n*. The difference $\left(n_{ij} - o_{ij}\right)$ between an observed and expected cell frequency is called a residual. The adjusted standardized residuals for two nominal variables[7] can be defined as (Agresti and Finlay, 2014, p. 230):

$$r_{ij} = \frac{n_{ij} - o_{ij}}{\sqrt{o_{ij}\left(1 - \frac{n_{i.}}{n}\right)\left(1 - \frac{n_{.j}}{n}\right)}} \qquad \text{for } i = 1,2...r;\ j = 1, 2, ...c \tag{1}$$

where $o_{ij} = \frac{n_{i.} \cdot n_{.j}}{n}$ are expected frequencies,

$\frac{n_{i.}}{n}$ is an estimated marginal probability in row *i*,

$\frac{n_{.j}}{n}$ is an estimated marginal probability in column *j*.

The denominator in formula (1) is a standard error of random variable $\left(n_{ij} - o_{ij}\right)$, when null hypothesis H_0 about statistical independence of variables is true. Adjusted standardized residuals r_{ij} follow asymptotically the standard normal distribution. They can be used to describe the pattern of the association among the table cells. A too large value of an adjusted standardized residual (greater than 2 in absolute value) indicates a deviation from independence in the cell.

2.1.3. Odds ratio

Let both variables are nominal. For a response variable with two values we use success to denote the outcome of interest and failure the other outcome. The odds of success is defined as

$$\text{Odds} = \frac{\text{Probability of success}}{\text{Probability of failure}}$$

The estimated odds[8] for a response variable with two values equals the number of successes divided by the number of failures. The odds ratio θ is a measure of association for 2 *x* 2 contingency tables that equals the odds in the 1st row divided by the odds in the 2nd row. For contingency tables with more than two rows or more than two columns, the odds ratio describes patterns in any 2 *x* 2 subtable. The odds ratios will be used as the measure of relative effectiveness of information channels in the framework of stated problem.

The situation is different in case of two ordinal variables. For *r* x *c* tables, odds ratios can use each pair of rows in combination with each pair of columns. The local, global and cumulative odds ratios are defined[9]. When variables are ordinal, the local odds ratios can be used for relative effectiveness of information channels measurement in the framework of stated problem.

3. THE STUDY OF INFORMATION CHANNELS ABOUT ACADEMIC ETHICS EFFECTIVENESS

The use of the just-mentioned methods in information channels effectiveness assessment will be illustrated on a study of two nominal variables associations that have been analyzed in a statistical study aimed to obtaining information about academic ethics program effectiveness at School of Management/City University of Seattle (VŠM/CU) in Trenčín and Bratislava sites. The study has been realized as a part of information flows and academic ethics knowledge management learning process in a wider context of knowledge management at this school.

The statistical survey was realized during 4 weeks in April and May 2013 by online application of the server Survey Monkey where an electronic questionnaire was created. There were considered many groups of students at VŠM /CU − according to place of study (Trenčín, Bratislava), mode of study (online, in-class), degree of study (bachelor, magister), language of study (Slovak, English) and the year of bachelor study (first, second and third). Each group defines one population. Each sample from the population had the size 150 students. The students were sampled by random sampling with replacement. At all, 914 students were contacted and 360 filled questionnaires were obtained. The overall response rate was 39.39 %. The questionnaire contains eight questions related with academic ethics program at VŠM /CU. The answers to the questions associated with diverse school branches, diverse degree of study, diverse modes of study, diverse year-class, diverse languages of study and diverse gender of students were analyzed. It was examined how students perceive functioning of the program, what are the preferred information sources as well as differences among diverse specific groups of students.

The question number 3 is: "How did you learn about academic ethics rules and procedures at VŠM?" The answers to this question related with two groups of students − studying in Slovak and studying in English will be analyzed in details.

3.1. Decision Making about Association between Information Channels and Groups of Students

The 67 students studying in Slovak language and 58 students studying in English language were sampled by random sampling with replacement. Originally there were 8 possible information channels. The joining of the columns with expected frequencies less than 5 was realized[10]. Three different information channels remaining after joining are

presented in Table no. 1. So finally we have two nominal variables – Information channels with three categories and Groups of students with two categories. The table includes expected frequencies in parentheses.

The chi-squared test of homogeneity was performed in Excel (using the statistical function − CHISQ.TEST). The obtained *p*-value was 0.006862. Thus at 0.05 level of significance we reject the null hypothesis that random sample from the Slovak language program students population and the random sample from the English language program students population come from the same probability distribution. Thus, we accept an assumption that there is an association between the information channels about academic ethics and the language of study. In other words, the information channels about academic ethics effectiveness differs by the language of study.

When the chi-squared test do not indicate association between variables, we can conclude that there are not differences among information channels effectiveness for different groups of people.

Table no. 1 − Distribution of Information Channels for Slovak and English Language Program Students after Joining of Columns

Information Channels **Language of study**	**1st Information Channel (New students orientation session)**	**2nd Information Channel (Teacher)**	**3rd Information Channel (Class syllabus, Web portal www.vsm.sk, Catalogue VŠM/CU, Classmates, Noticeboards, Other sources)**	$n_{i.}$
Slovak language	2 (6.97)	4 (5.36)	61 (54.67)	67
English language	11 (6.03)	6 (4.64)	41 (47.33)	58
$n_{.j}$	13	10	102	125

Source: own

3.2. Revealing the Information Channels Relative Effectiveness by Residual Analysis

The adjusted standardized residuals were calculated according to (1), to find the cells "responsible" for the association. The results are in Table no. 2.

Table no. 2 − Information Channels and Adjusted Standardized Residuals for Different Language of Study Students

Information Channels **Language of study**	**1st Information Channel (New students orientation session)**	**2nd Information Channel (Teacher)**	**3rd Information Channel (Class syllabus, Web portal www.vsm.sk, Catalogue VŠM/CU, Classmates, Noticeboards, Other sources)**
Slovak language	-2.92	-0.9	2.93
English language	2.92	0.9	-2.93

Source: own

There is considerably great positive value of residual concerning students studying in English language obtaining information about academic ethics through the first information channel − at new students orientation sessions in the Table no. 2. For students studying in Slovak language there is a considerably great negative value of residual in the same column. This means that there are more students studying in English who obtain information through the first information channel than it is suggested by the homogeneity hypothesis. The great negative residual in the same column for students studying in Slovak means that there are less students studying in Slovak who obtain information through the first information channel than it is suggested by the homogeneity hypothesis.

The great positive value of residual in the fourth column concerning students studying in Slovak indicates that there are more students studying in Slovak who obtain information through the third information channel than it is suggested by the homogeneity hypothesis. The great negative residual in the same column for students studying in English means that there are less students studying in English who obtain information through the third information channel than it is suggested by the homogeneity hypothesis.

We can conclude that students studying in English are more likely to obtain the information through the first information channel − at new students orientation sessions than students studying in Slovak. The students studying in Slovak are more likely to obtain the information through the third information channel than students studying in English. In other words the first information channel is relative more effective for students studying in English than for students studying in Slovak. The third information channel is relative more effective for students studying in Slovak than for students studying in English.

It is also clear from Table no. 2 that there is no important difference between effectiveness of second information channel for the students studying in Slovak and in English. That means also that among Slovak and English program teachers is not difference in providing information about academic ethics. This is also very useful information for information channels assessment and finally for information flows managing.

3.3. Information Channels Relative Effectiveness Assessment

Odds ratio analysis will be applied. This analysis enables to take in consideration all cells of contingency table where association was revealed by residual analysis. The subtable with the second and forth columns of Table no. 1 will be analyzed. The data are in Table no. 3. The association strength measured by odds ratio will be understood and interpreted as value of relative effectiveness.

Table no. 3 − Subtable of Table no. 1

Information Channels **Language of study**	**1st Information Channel (New students orientation session)**	**3rd Information Channel (Class syllabus, Web portal www.vsm.sk, Catalogue VŠM/CU, Classmates, Noticeboards, Other sources)**	**Total**
Slovak language	2	61	63
English language	11	41	52

Source: own

The relative effectiveness assessment of the first information channel for the students studying in English in comparison to the students studying in Slovak will be realized. The first information channel (second column) will represent a success and the third one (third column) a failure.

The estimated odds for students studying in English is:

$$\frac{\frac{11}{52}}{\frac{41}{52}} = \frac{11}{41} \approx 0.268$$

As far as students studying in English are concerned, there are about 0.268 of a student who obtained information through the first information channel per 1 student who obtained the information through the third information channel.

The estimated odds for students studying in Slovak is:

$$\frac{\frac{2}{63}}{\frac{61}{63}} = \frac{2}{61} \approx 0.033$$

As far as students studying in Slovak are concerned, there are about 0.033 of a student who obtained information through the first information channel per 1 student who obtained the information through the third information channel.

The odds ratio for students studying in English and for students studying in Slovak can be calculated as follows:

$$\theta = \frac{0{,}268}{0{,}033} \approx 8.121$$

The student studying in English has 8.121 times greater chance to obtain information through the first information channel − at the new students orientation session than a student studying in Slovak language. This value can be considered as the assessment of relative effectiveness of the first information channel for the students studying in English in comparison to the students studying in Slovak. So the first information channel is relatively 8.121 times more effective for students studying in English than for students studying in Slovak.

It can be easily shown that when the third information channel represents success and the first one, failure, the same odds ratio for the students studying in Slovak will be obtained. The student studying in Slovak has 8.121 times greater chance to obtain information through the third information channel than a student studying in English language. So the third information channel is relatively 8.121 times more effective for students studying in Slovak than for students studying in English. This relation concerning odds ratios in contingency subtables is generally valid. The analysis of the first and second and the second and third information channels can be realized by the same way.

4. PROCEDURE OF INFORMATION CHANNELS EFFECTIVENESS ASSESSMENT

Generally, the different information channels are expressed by the *c* values of the first categorical variable, the *r* populations − groups of people obtaining information through these information channels are represented by values of second categorical variable. Observed frequencies n_{ij} are obtained on the basis of answers of respondents sampled by random sampling with replacement from each from *r* populations. The respondents indicate the information channel they obtained information through.

Then the testing of homogeneity is applied. When the test indicates no association between variables, it can be concluded that the effectiveness of information channels is not significantly different for different groups of people. When the test indicates the association, the residual analysis is recommended.

Residual analysis with aid of adjusted standardized residuals determines the cells of contingency table "causing" association. The residuals greater than 2 in absolute value indicate the cells "responsible" for association. When $r_{ij} > 2$, the corresponding information channel is more effective for corresponding group of people as for other groups, when $r_{ij} < -2$, the corresponding information channel is less effective for corresponding group of people as for other groups. So, relative effectiveness of information channels for different groups of people can be determined by this analysis.

Finally, information channels effectiveness assessment on the basis of odds ratios[11] is recommended:

- Each 2 *x* 2 subtable to be analyzed contains at least one cell with $|r_{ij}| > 2$.
- The estimated odds are calculated for the first channel from the left as success and for the second channel from the left as failure. Then the odds ratio can be calculated with the greater odds in numerator. The result is the odds ratio for the group with greater value of odds.
- The calculated odds ratio is the same for the second channel from the left as success and for the first channel from the left as failure, for the group with less value of odds.
- The odds ratio is understood and interpreted as value of information channels relative effectiveness.

5. CONCLUSIONS

We showed in the paper how to use the data from statistical survey and some methods of analysis of association between two categorical variables in the information channels effectiveness assessment. The testing of association enables to make decision about whether there exists an association between variables one of which represents information channels and second one, different groups of people obtaining information by these information channels.

When the test indicates that there is not an association between variables, the conclusion that there is not important difference in relative effectiveness of information channels for different groups of people can be accepted. Once an association between variables is established, the using of residual analysis is recommended. This statistical tool enables to determine which combinations of variables values cause the revealed association. The identification of cells "responsible" for association in a contingency table enables to recognize the relative effectiveness of information channels for different groups of people.

When there is a great positive value of the adjusted standardized residual in the cell, corresponding information channel is more effective for the corresponding group of people. When there is a great negative value of the adjusted standardized residual in the cell, corresponding information channel is less effective for the corresponding group of people.

The using of odds ratios is recommended for information channels relative effectiveness measuring. This characteristic can be calculated for all more effective information channels revealed by residual analysis.

In the application of the proposed procedure in the analysis of answers to question 3 from realized statistical survey, the results that the first information channel is relatively 8.121 times more effective for students studying in English than for students studying in Slovak and the third information channel is relatively 8.121 times more effective for students studying in Slovak than for students studying in English were obtained. In the context of information flows management in the area of academic ethics at VŠM/CU, one of the most important objectives is to provide the academic ethics rules to all students as soon as possible that means at the beginning of studies, for example during new students orientation session[12]. The results of the analysis show that whereas the new student orientation session is an effective information channel for students studying in English language, it is not for students studying in Slovak language. It is clear that new student orientation session is visited more by students studying in English language but no so frequently by students studying in Slovak language. So some modification of existing or creation some new, more effective information channels for students studying in Slovak language can be recommended. The realized statistical study provided naturally also another interesting results utilizable mainly in the process of information flows control at VŠM/CU, but the applied methodology could be useful also for other universities.

Described procedure of analysis can be used also in a lot of others contexts. For example, it is current practice to ask the hotel guests to fill the questionnaires with questions one of which is frequently "how did you learn about our hotel?" Each gest has to show in hotel reception desk identity card where are names, date of birth, domicile and so on. In this case the testing of independence could be realized. The testing procedure is the same as in the case of homogeneity testing. The similar analysis as described could be realized on the basis of the data from survey by hotel management. Obtained information could be very useful for example in some marketing activities. The using of some specialized statistical software is not required in order to perform the analysis, Excel is fully sufficient.

The described procedures could be used not only for the information channels effectiveness assessment. For example for a hotel management could be interesting the association between satisfaction with services in the hotel and different groups of guests and so on.

Acknowledgements

This paper was prepared with the support of the project VEGA no. 1/0092/15: Modern Approaches to Complex Statistical Surveys Design.

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Notes

[1] A variable is called categorical when the measurement scale is a set of categories. When the categories are unordered, the corresponding measurement scale does not have a „high“ or „low“ end. The categories are then said to form a nominal scale and the corresponding variables are called nominal. When the measurement scale of variable has a natural ordering of values, the corresponding variable is called ordinal.

[2] More in details see Kročitý, 2015.

[3] If both variables are nominal. In case of ordinal variables there are another possibilities.

[4] An alternative method see in Agresti, 2010, p. 73.

[5] See for example in Anderson *et al.*, 2007.

[6] See in Agresti and Finlay, 2014, pp. 241-244

[7] For ordinal variables see in Agresti, 2010, pp. 73-74.

[8] Calculated value is only estimate of the real unknown value of odds in the population that is why it is called estimated.

[9] Detailed description is in Agresti, 2010, pp. 14-22.

[10] It is necessary for realization of testing by Pearson chi-squared test (see for example Freund, 1992 or Tošenovský and Noskievičová, 2000).

[11] Local odds ratios in case of ordinal variables.

[12] It is the first information channel.