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BRIEF REVIEW OF LOGIT MODELS APPLICATIONS IN REGIONAL STUDIES

WYKORZYSTANIE MODELI LOGITOWYCH W BADANIACH REGIONALNYCH – KRÓTKI PRZEGLĄD

Summary: The problems referring to the functioning of economy are closely related to a territory. The place of their occurrence, whether it is a country, a region or a smaller territorial unit, implies the scale and the benchmark for carrying out analyses. Numerous phenomena within the area of economic research are of complex nature and, moreover, it is frequently difficult to express them in a measurable form. The solution to such "inconvenience" is e.g. the application of qualitative variables. Logistic regression is one of the tools allowing the assessment of dependence and prediction in case of qualitative variables of dichotomous type. The purpose of the study is to review the applications of logit models in regional studies.

Keywords: review, logit models, regional studies.

Streszczenie: Funkcjonowanie gospodarki jest ściśle związane z terytorium. Kraj, region czy mniejsza jednostka terytorialna implikują skalę i punkt odniesienia dla analiz. Wiele zjawisk w badaniach ekonomicznych ma złożony charakter, a dodatkowo często trudno je wyrazić w postaci mierzalnej. Rozwiązaniem tej „niedogodności" jest m.in. zastosowanie zmiennych jakościowych. Jednym z narzędzi umożliwiających ocenę zależności i predykcję w przypadku występowania zmiennych jakościowych o charakterze dychotomicznym jest regresja logistyczna. Celem pracy jest przegląd zastosowań modeli logitowych w badaniach regionalnych.

Słowa kluczowe: przegląd, modele logitowe, badania regionalne.

1. Introduction

Models in which the dependent variable takes two values 0 and 1 (a dichotomous variable) are useful in a situation when it is necessary to assess the chance of an event occurrence (the predicted phenomenon). The advantage of logit models is the

ability to identify the statistically significant risk factors of a tested unit experiencing a particular condition and to examine the effects of interactions between these factors. The possibility to interpret logit model parameters remains its important advantage.

Today logit models are used in many areas of science and economy sectors. The methods of logit regression are used by the banking sector (credit risk assessment), by entrepreneurs (customer loyalty assessment), actuaries (insurance risk), insurers (risk of death), demographers (life expectancy process) and physicians (case-control studies), sociologists (voting preferences), marketers (the purchase of goods) and coaches (sports success factors). The research covering economic entities, companies, institutions, households cannot remain isolated from space, therefore there is the broad spectrum of logistic regression applications in regional studies.

The purpose of the study is to review the selected logit models' applications in regional studies.

2. Logistic regression – short characteristics

Logistic regression (logit regression, logit model) is a regression model where dependent variable is categorical. If there are only two outcomes we have binary logistic regression, and with more than two outcomes it is referred to as multinomial logistic regression. Definitely the first case is more popular in literature and applications so the shorter expression "logistic regression" should be understood as binary logistic regression. Logistic regression was introduced by Cox [1958]. For binary regression we usually consider 1 as a success (event, case) and zero as a failure (no event) and we are interested in modelling the probability of an event depending on some explaining variables, categorical or continuous. For the binary case, dependent variable Y follows Bernoulli distribution with parameter p which is $P(Y = 1)$. Then we can define so called *odds* as:

$$odds = \frac{p}{1 - p}.$$

This is the ratio of probability of success by the probability of failure. If the probability of success is 0.5, the odds are one-to-one (or 50/50) or even. The logarithm of odds is called *logit* or *log-odds*.

$$logit(p) = log\frac{p}{1-p}.$$

When the probability of success goes to zero, the odds approach zero, and the logit goes to $-\infty$. As the probability approaches one, the odds and the logit approach $+\infty$. Negative logits represent probabilities below 0.5 and positive logits correspond to success probabilities above 0.5.

Assuming that probability depends on explanatory variables in such a way that logit is a linear function of predictors we have:

$$logit(p) = X^T \beta.$$

Equalling right sides of the last two formulas and solving for p we come to the logistic regression equation:

$$p = P(Y = 1) = \frac{\exp(X^T \beta)}{1 + \exp(X^T \beta)} = \frac{1}{1 + \exp[-(X^T \beta)]}.$$

Parameter vector β is estimated by maximum likelihood method with the procedure equivalent to re-weighted least squares. For testing the statistical significance of regression parameters the Wald statistic can be used. It is the ratio of the square of the regression coefficient to the square of the standard error of the coefficient and it is asymptotically chi-square distributed. Also the classical t statistics is used by some researchers.

For the purpose of interpretation β parameters are not useful, but the odds ratio, given as:

$$OR_j = \exp(\beta_j).$$

The odds are being multiplied by $\exp(\beta_j)$ for a unit increase of X_i variable assuming that other predictors are kept constant. The unit increase of X_j gives $100 \times (\beta_j - 1)$ change in odds. For example OR = 1.41 means the increase of odds (relative risk of $Y = 1$) by 41%, and OR = 0.92 – the decrease by 8%.

3. Logit models in regional studies

Examples of such applications in regional studies are for the evaluation of relations between:
- enterprise size and ownership structure vs. innovation development in the regional industrial systems [Świadek 2012], and
- the size of enterprises vs. innovation of the regional industrial system in the region [Świadek, Tomaszewski 2013; Świadek, Szopik-Depczyńska 2014],
- economic prosperity and the assessment of financial situation from the perspective of households [Kowerski, Bielak 2013],
- foreign direct investments and inadequately educated workforce [Goczek 2013],
- unemployment risk and the place of residence (country region, its urban or rural nature) and demographic characteristics [Markowicz 2013],
- minimum wage and the job market situation [Ruzik 2007],
- transport impact assessment on spatial management [Koźlak 2011],
- analysis of the influence of railway transport improvement on business trips [Bhat 1995],
- the importance of geographical distance from suppliers and the impact of mutual relationships on enterprise innovations in the area of regional industrial systems [Świadek, Szopik-Depczyńska 2011],

- socio-demographic variables, the condition of transport systems and land use and decisions about the choice of residence [Bhat, Guo 2004].

The proposal of logit models' application to identify the strategic areas of economy in terms of smart growth of regions, in the context of their vulnerability to crisis phenomena [Markowska 2017], offers an interesting approach. The study also verifies the relationships between variables characterizing smart growth of the European Union regions at NUTS 2 level, including their vulnerability to economic crisis.

Among the examples of regional studies using logit models also the ones allowing the identification of factors affecting changes in the selected aspects of economy should be mentioned. The specification of the following implying determinants can be indicated here:

- EU funds accessibility by municipalities [Standar 2010],
- job satisfaction [Kaczkowska-Serafińska 2012],
- product choice by consumers (preference analysis) [Tłuczak 2014],
- product consumption by households selected groups [Podolec et al. 2011],
- clients' insolvency [Marzec 2003],
- financial problems of households [Anioła, Gołaś 2012],
- decision-making process in a household [Sagan, Łapczyński 2014],
- choice of an airport (research review in the study by [Hess, Polak 2005]),
- social mobility [Sokołowska 2013],
- economic activity of population [Śliwicki, Ręklewski 2012],
- life quality improvement felt by women [Sompolska-Rzechuła, Machowska-Szewczyk 2010],
- succession of farms [Dudek 2009],
- liquidation process of individual farms [Dudek 2010],
- value improvement of Local Human Development Index (LHDI) in Polish counties [Sompolska-Rzechuła 2015],
- foreign direct investments in international service companies [Li, Guisinger 1992],
- innovation of European companies [Sternberg, Arndt 2001],
- risk of poverty [Czapiński, Panek (eds.) 2009; Kasprzyk, Fura 2011; Rusnak 2012],
- the limited access to enterprise financing [Goczek 2012] and company financial risk prediction [Waszkowski 2013],
- sustainability of farms [Wrzaszcz 2012],
- the choice of place and form of having holidays [Eyman, Ronning 1997],
- changes in wage differentiation and the diversification in the levels of jobs opening and closing [Marcinkowska et al. 2008],
- evaluation of the importance of knowledge-intensive services in stimulating innovation [Majewska, Truskolaski 2013].

Logit models are also applied in the assessment of:
- regional economic situation diagnosis and forecasting [Batóg, Wawrzyniak 2011],
- capital market situation diagnosis and forecasting [Batóg, Wawrzyniak 2010],
- assessing bankruptcy risk [Kaczmarek 2012], company bankruptcy prediction (e.g. [Ohlson 1980], and a brief review of Polish models[1] is presented in the studies by e.g. Kisielińska, Waszkowski [2010] and Pociecha [2014]),
- analysing transactions on the housing market [Batóg, Foryś 2011],
- economic evaluation of the situation on individual farms [Ryś-Jurek 2006] and the analysis of subjective structures in agriculture [Ryś-Jurek 2005],
- evaluating the probability of social status change [Deary et al. 2005].

Moreover, the multi-level model was used in identifying the impact of factors of micro, mezzo and macro type on unemployment risk and the measurement of probability variation scale at the particular levels of spatial aggregation [Łaszkiewicz 2013]. However, as Łaszkiewicz [2013] pointed out the existing studies were most frequently focused on analysing (using two-level models) the disproportions occurring within the area of an individual country – e.g. Great Britain [Gould, Fieldhouse, 1997], or Australia [Haynes et al. 2011; Baum, Mitchell, 2009; 2011] – or even smaller spatial units – e.g. districts of Beijing [Poston, Duan 2000]. Among international analyses the study by Domański and Pokropek [2011] should be mentioned, who applied a two-level model with a macro level.

Logistic regression was used as the evaluation method in deforestation problems [Geoghegan et al. 2001; Schneider, Pontius 2001], agriculture [Serneels, Lambin 2001; Walsh et al. 2001], urban development modeling [Wu, Yeh 1997; Landis, Zhang 1998; Allen, Lu 2003; Hu, Lo 2007; Cheng, Masser 2003; Luo, Wei 2009], and to explain land use and company location [Wu, Yeh 1997; Wu 2000].

As Chen [1996] – who evaluated logit models application in the analysis of foreign direct investments – pointed out, the conditional logit model (CLM), suggested by McFadden [1974] and developed by Carlton [1983], Bartik [1985; 1989], Coughlin et al., [1991] and Woodward [1992] was used in testing the impact of variables determining the regional potential on the decisions regarding foreign direct investments location.

4. Conclusion

The range of logit models' application refers not only to macro, but also to mezzo and micro scale, whereas the presented brief review of research areas shows that the spectrum of their applications in economic research is extremely wide. Generally three main groups of research can be identified: investigation of relations between economic phenomena on regional level, identification of factors determining state and changes in regions, and the third one consisting diverse applications outside the above two groups of problems.

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[1] Bankruptcy models have even their author's names, e.g. Gruszczyński's models.

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