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SELECTED HAZARD MODELS IN APPLICATION TO ANALYSES OF UNEMPLOYMENT

1. Introduction

The subject of the testing is the analysis of results of the survey study carried out i.e. the Testing Economic Activity of Population in Poland. Random and representative control group incorporated in the testing carried out by the Polish Central Statistical Office (GUS) included the group of more than 54 thousand Poles. On the basis of the available set of questionnaires, the characteristics of people out of wok have been made according to the demographic and social covariates which statistically have a considerable influence on the time of being unemployed and able and willing to work.

The aim of presented analysis is adaptation and empirical verification of the usefulness of selected statistical tools characteristic of survival analysis used for the determinant identification and description of the situation on the labour market in Poland. In particular, the aim of the authors is to check the usefulness of selected D. R. Cox's models (parametric and non-parametric) for estimation of the relationship connected with the risk of experiencing long-term unemployment.

2. Historical background of Poland and the European Union countries

The biggest social and economic problem in Poland at the turn of the centuries is high unemployment rate. The situation of permanent imbalance on the labour market manifesting itself in the domination of supply over the

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demand for workplaces occurred in the moment of reforms. However, in recent years, the number of unemployed people, i.e. people out of work, but actively looking for a job and able to work is alarmingly high[1].

The synthetic measure of the unemployment is unemployment rate. The comparison made in 15 member countries of the EU and in Poland in the years 1993–2002 demonstrates the following regularities:

▪ in the EU countries (excluding Greece) there is a downward trend of the phenomenon,

▪ the fastest decline in the rate of unemployment is in Ireland,

▪ the average rate of unemployment in the EU countries fluctuates between 2.6% (Luxembourg) and 15.4% (Spain), the smallest diversity was noticed in Austria (0.31%), whereas the biggest in Ireland (4.39%).

▪ the tendency of changes in the unemployment rates in Poland is incomparable with other EU countries. The crucial moment for Poland was year 1998 when the downward trend of the years 1993–1997 changed into the permanent upward trend. The achievement of the period of 1993–1997 was evened up in the following years and continues until today. The measurable consequence of this is higher middle year rate of the unemployment rate rise in the years 1997–2002 (by 0.2%) in comparison with the average dynamics of decline between 1993–1664 (by 1.5%) – see Figure 1.

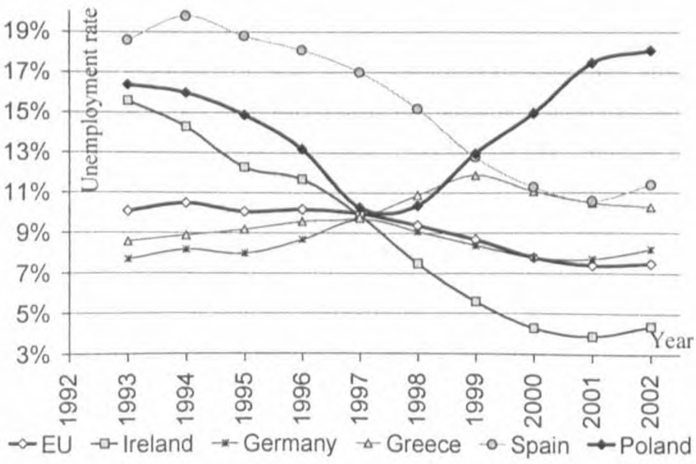

Fig. 1. Unemployment rate in UE countries and Poland in 1993–2002
S o u r c e: Own description based on Eurostat Survey.

[1] According to recommendations of EUROSTAT the International Work Organisation and European Statistic Office, the requirement for classifying a person to the group of unemployed is meeting the listed three conditions. The same criterion is applied by the GUS In BAEL additionally specifying that the unemployed person can be a person who is at least 15 and not older than 74 years old.

There is a heated pre referendum discussion about the direction of transformations of Polish imbalanced labour market perceived most of all through the prism of unemployment. The comparison analyses of unemployment in time line, in the EU member countries indicate that in the past in many of them the rate of unemployment raised just before a country's accession and during the first years of membership (Nowak 2003, pp. 7–9). If this regularity was to take place in Poland, it is justified to identify a European Union country whose labour market underwent changes in a similar way in the past.

The country to which unemployment in Poland is most often compared is Spain. The comparison is justified by the convergence in the tendency of changes in unemployment rates in Poland and in Spain having assumed eight-year-period of delay – see Fig. 2.

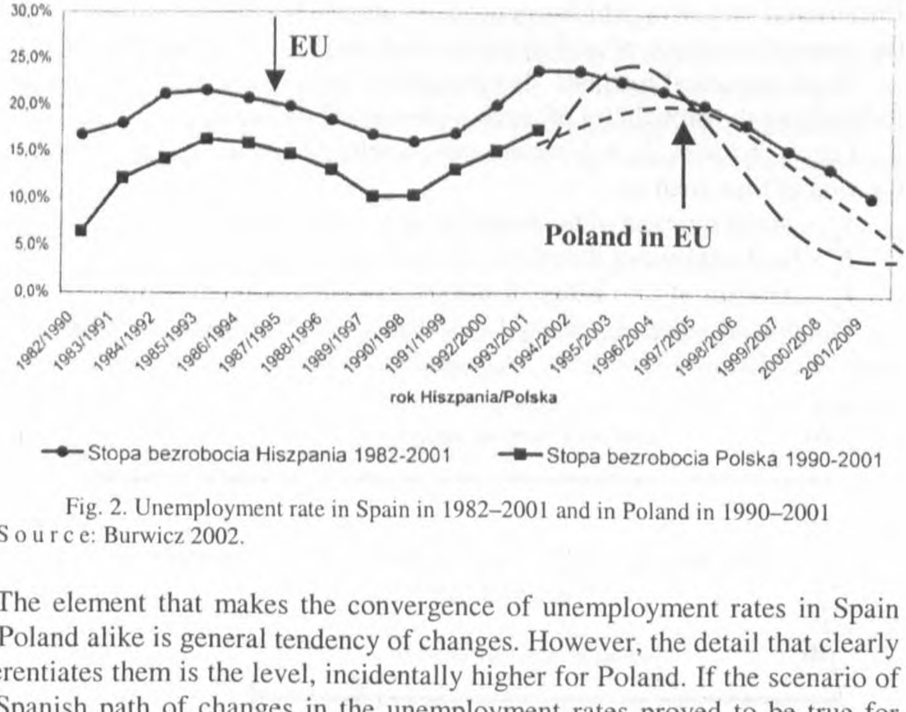

Fig. 2. Unemployment rate in Spain in 1982–2001 and in Poland in 1990–2001
Source: Burwicz 2002.

The element that makes the convergence of unemployment rates in Spain and Poland alike is general tendency of changes. However, the detail that clearly differentiates them is the level, incidentally higher for Poland. If the scenario of the Spanish path of changes in the unemployment rates proved to be true for Poland (even if slightly delayed in time), the essential condition for Poland is the country's accession to the European Union. And having considered the level reserve and the close perspective of our accession to the EU, the discussion about hypothetical scenario of the situation of changes on the labour market in Poland is open. Figure 2 demonstrates two of them with a dashed line. On the basis of the optimistic course of unemployment rate in Poland in the near future, the assumption is made about dynamically developing positive changes of national economy in Poland and the positive influence of external conditions.

3. Theoretical analysis tools – survey methodology

The duration (survival) analysis does not belong to the standard set of statistical analysis methods. It is a special method for performing the results of studies based on individual data in conditions of having incomplete data set. The subject of interest of the survival analysis[2] is the duration time of the phenomenon, and especially, the length of transition time from one state to another for individuals (that is the changes of status quo of an individual, a case or a person). The change in the position (state) of an individual is known as "death". So, there are two types of time data: censored and relapsed. Observation is called censored (by the period of analysis) if during the time of performing survival analysis an object did not change its state. It is relapsed () otherwise. Uncensored time data, which can occur, is not predicted. The inability to predict the moment of change of an individual's state means incomplete data set.

These statistical methods also provide an appropriate analytical framework for studying the probability of leaving the state of definite phenomena.

Let t_i $\left(i = p,\ k,\ \bullet\right)$ means three spells of individual observation over a period of time such as:

t_p – initial moment of the period of survival analysis,

t_k - final moment of the period of survival analysis,

$t_\bullet$ – moment of the change of state (status quo) of an individual.

The crucial point of censored observation on the time axis (t) in survival analysis is illustrated in Figure 3A) and 3B).

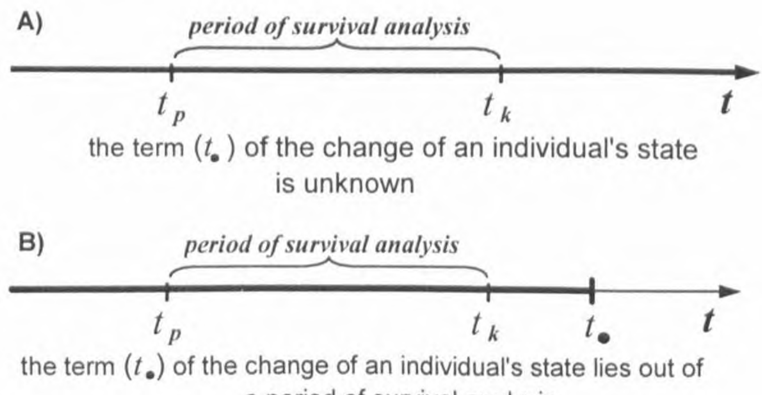

Fig. 3. Censored observation In survival analysis

[2] The term survival analysis is known in biomedical science and demography. It is called the duration analysis in economic applications and reliability analysis in engineering applications.

It happens that the change of an individual state takes place in the period of survival analysis. Such observation is called relapsed (uncensored), and it is illustrated in Figure 4.

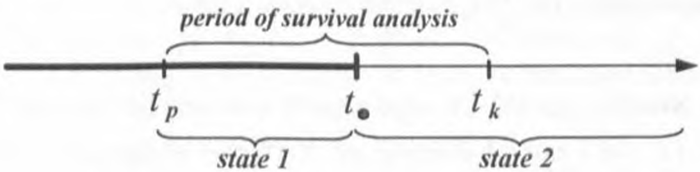

Fig. 4. Relapsed observation in survival analysis

The pioneers of survival analysis are: D.R. Cox and D. Oakes. Their monograph entitled *Analysis of survival data* published in 1984 greatly contributed to the theory and practice of this testing method.

One of survival analysis methods is causal models. They are built similarly to classical regression equations. Nevertheless, in order to characterise the relationships between the risks of long term period of being in a definite state, it is unfounded to use simple methods of multiple regression for the following reasons:

- the complexity of distribution of dependent variable which is the time of duration (most often undergoes exponential or Weibull distribution),
- occurrence of censored observations.

The reasonable tool is Cox regression being the method for modeling time-to-event data in the presence of censored cases.

Parametric causal models used in time data analysis (for cases being in a definite state) are (Stanisz 2000, p. 349):

– model of linear regression: $t = a_0 + \sum_{j=1}^{n} a_j x_j + \varepsilon$, (1)

– log-normal regression model: $ln(t) = a_0 + \sum_{j=1}^{n} a_j x_j + \varepsilon$, (2)

– exponential model: $S(t) = exp\left(a_0 + \sum_{j=1}^{n} a_j x_j + \varepsilon \right)$, (3)

however, *non-parametric* group comprises of:

– Cox's proportional hazard model: $h(t) = h_0(t) \cdot exp\left(\sum_{j=1}^{n} a_j x_j \right)$; (4)

– Cox's proportional hazard model with explanatory variables depended on time:

$$h(t) = h_0(t) \cdot exp\left(\sum_{j=1}^{p} a_j x_j + \sum_{k=1}^{q} b_k x_k(t) \right). \tag{5}$$

In formulas (1)–(5) the argument of a hazard function x_j (x_k) indicates $j-th$ $(k-th)$ case of determinant X (factor, explanatory variable) of being an individual in invariable state.

In the first two models, it is assumed that the survival time (or log survival times) comes from a normal distribution. If lognormal regression is requested, t is replaced by its natural logarithm. The estimators are computed by using a very efficient method, the so-called expectation maximization (EM) algorithm, for obtaining the maximum likelihood estimates for this model. In exponential model (3), it is assumed that the distribution of dependent variable is exponential. The usual method to estimate the structural parameters of parametric models is by maximum likelihood (ML).

Cox's non-parametric model ((4) and (5)) – contrary to parametric models – is focused on the changes of the hazard function factored by a function of elapsed duration t and the function of explanatory X variable. The proportional hazard model (4) is the most general of the regression models. It does not make any assumptions about the nature or shape of the underlying survival distribution. The model assumes that the underlying hazard rate[3] (rather than survival time) is a function of the independent variables (covariates); thus, in a sense, Cox's regression model may be considered to be a nonparametric method. Model N° (4) only assumes that the risk of failure the state over time depends on:

• changes of contingent on the particular covariate vector X (independent variables),

• the so-called base-line hazard $h_0(t)$ (referred also as the zero hazard line when the values for all independent variables (i.e., in X) are equal to zero) with unknown form of a function.

In this model only base-line hazard function depends on time t. Other explanatory factors, which are comprised in the log-linear function, are not correlated with time t. Thus, another assumption called *proportionality* is made. This is, therefore, assumed that the proportion of hazard assigned for two different moments does not depend on time t and is specified as:

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[3] The hazard rate is defined as the probability per time unit that a case that has survived to the beginning of the respective interval will fail in that interval. Specifically, it is computed as the number of failures per time units in the respective interval, divided by the average number of surviving cases at the mid-point of the interval.

$$\frac{h\left(t,\ x_1, x_2, \ldots, x_n\right)}{h\left(t,\ x_1', x_2', \ldots, x_n'\right)} = exp\left(\sum_{j=1}^{n} a_j \left(x_j - x_j'\right)\right) \tag{6}$$

The aim of these exploratory analyses is to identify the determinants of the changes of phenomena in time. It implies the necessity of dividing (stratification) of sampling (control group). If in every separated stratum (sub-set) different hazard functions occur, then the *stratum analysis* is likely to occur in Cox's proportional hazard models. It is useful for:

- discovering complex and unknown (therefore difficult to identify) interactions between explanatory variables and time of survival of every stratum,
- verification of diversification for the dependence in every stratum.

The assumption of proportionality is disproved in other non-parametric hazard models (5) since in many cases it is not possible to make an unconditional assumption of independence of time and explanatory variables. Methods of the evaluation of the dependence of explanatory variable to time are:

– analysis of hazard function figures prepared for two or several sub-sets of this variable (they should not cross) and

– verification of the hypothesis of statistical significance of a variable which is considered to be dependant on time, after having previously developed the model described by equation (4) to the form of model (5').

The estimation method of the parameters of both non-parametric hazard models (after having transformed them into a more simple form) is by the maximum likelihood with incomplete data set. The goodness-of-fit measure is computed as usual, that is, as a function of the log-likelihood for the model with all covariates, and the log-likelihood of the model in which all covariates are forced to 0. The significant value of chi-square $\left(\chi^2\right)$ – statistics obtained in increment test[4] – proves the hypothesis stating that the independent variables have significant influence on the time of survival of individuals (cases). The results spreadsheet with the parameter estimates for the Cox non-parametric hazard regression model includes the so-called Wald statistic, and the p-level for that statistic. This statistic is based on the asymptotic normality property of maximum likelihood estimates. The Wald statistic is tested against the chi-square distribution. The estimators of non-parametric Cox's models are interpreted as hazard ratios. They show the scale of increasing risk leaving the definite state by $\left|e^{\beta_j} - 1\right| \cdot 100\%$ if the X_j determinant rises by one unit.

[4] The value of test is equal to doubled difference of the logarithm of likelihood function for model together with all explanatory variables and the logarithm of likelihood function for the model in which independent variables were replaced with zeros.

4. Characteristics of BAEL control group

4.1. Principles of rotation and selection of individuals for the test

The survey of economic activity of population (BAEL) in Poland has been carried out by GUS since May 1992. Until the fourth quarter of 1999 it took place in specifically determined periods of time. In fixed in advance and always in the same week of February, May, August and November members of approximately 20 thousand households, randomly chosen, having considered the representative factor of the control group, gave answers about their professional status. At present, the survey is carried out all year round with the so called movable survey week. This means that every week (it is assumed that there are 13 weeks in a quarter) members of the households which were drawn from the quarterly control group are surveyed and constitute thirteenth part. Invariably since the second quarter of 1993, quarterly control groups are selected rotationally. Every time the quarterly control group in the number of 24440 flats is divided into 4 subgroups, and every quarter two of them are changed. One of them is totally new and the other one is the one which was surveyed in exactly the same quarter of the previous year. Individuals of particular subgroups are selected randomly and independently from the results of the drawing to other subgroups. In the "lifetime" of every established subgroup, the group is observed for two subsequent quartets of the year. The survey period is suspended for half a year, and then again reactivated only for a half-a-year period, and then the group comes to an end of its life.

Individual time data sets, which are a subject to this analysis, come from the control group number 12, i.e. surveyed in February 1995. In the initial period of the labour market research (until May 1999), GUS made observations with quarterly frequency and always in the middle month of every quarter.

4.2. Demographic and social structure of the control group

The structure of BAEL control group being a subject to empirical analysis in several selected demographic and social sections is presented in Figure 5–7.

BAEL control group comprises of males in 47.5%. Regardless of sex, the most numerous is the group of economically active people (48.6%). 8.4% out of the whole population surveyed are unemployed persons – see Figure 5a and 5b.

In the survey GUS distinguishes seven education categories, i.e. tertiary (university), post secondary, secondary vocational, general secondary, basic vocational, primary and incomplete primary. The biggest group is represented by the population with primary education (19.2 thousand) , in the next place with basic vocational (14.0 thousand). The smallest group is represented by the population with post secondary education (1.2 thousand). In the light of the distinguished professional activity categories, the widest diversity is among population with general secondary education, and in the second place basic vocational, however the least diverse is the population with incomplete elementary education – see Figure 6.a–6.d.

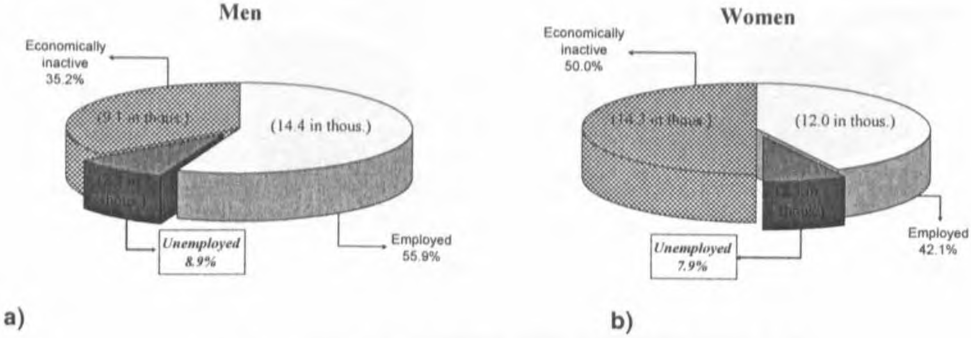


Fig. 5. Economic activity of the population In Poland by sex
S o u r c e: Own scheme based on BAEL data In February 1995.

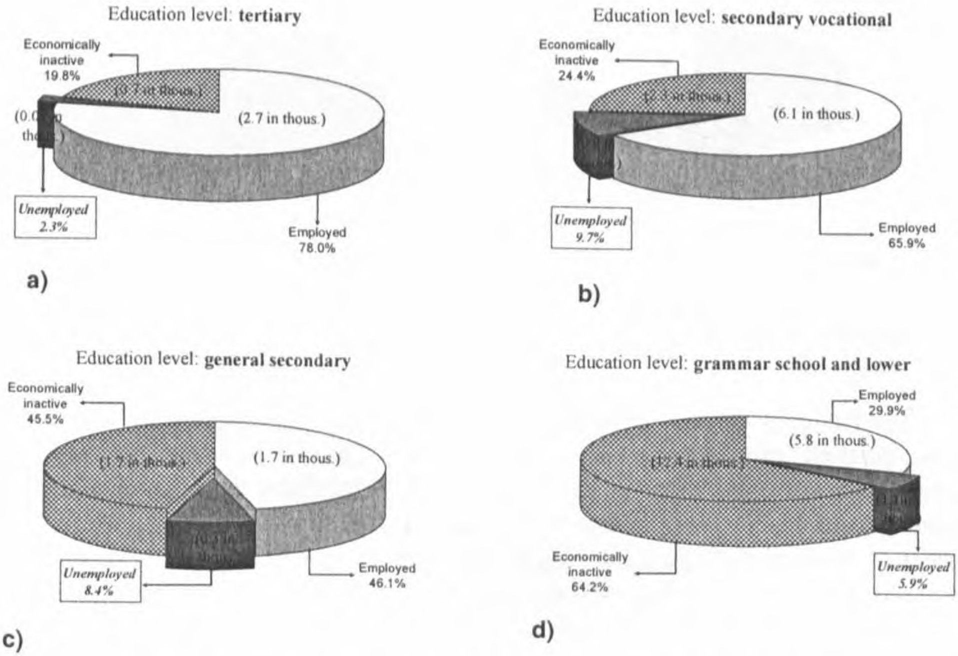


Fig. 6. Economic activity of the population In Poland by the level of education
S o u r c e: As same as Fig. 5.

The structure of professional activity of the population surveyed according to the place of residence and considering the division into urban and rural as it is illustrated in Figure 7a–7b.

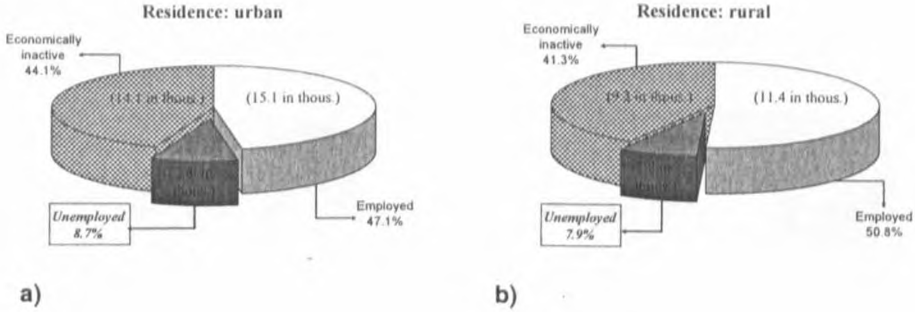


Fig. 7. Economic activity of the population In Poland by place of residence
S o u r c e: As same as Fig. 5.

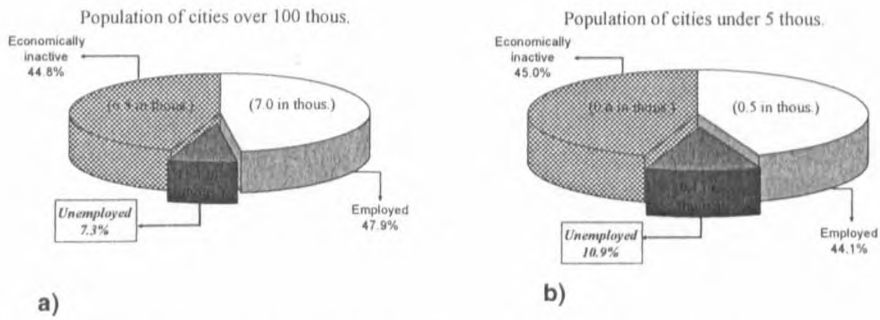


Fig. 8. Economic activity of the population In Poland by urban residence
S o u r c e: As same as Fig. 5.

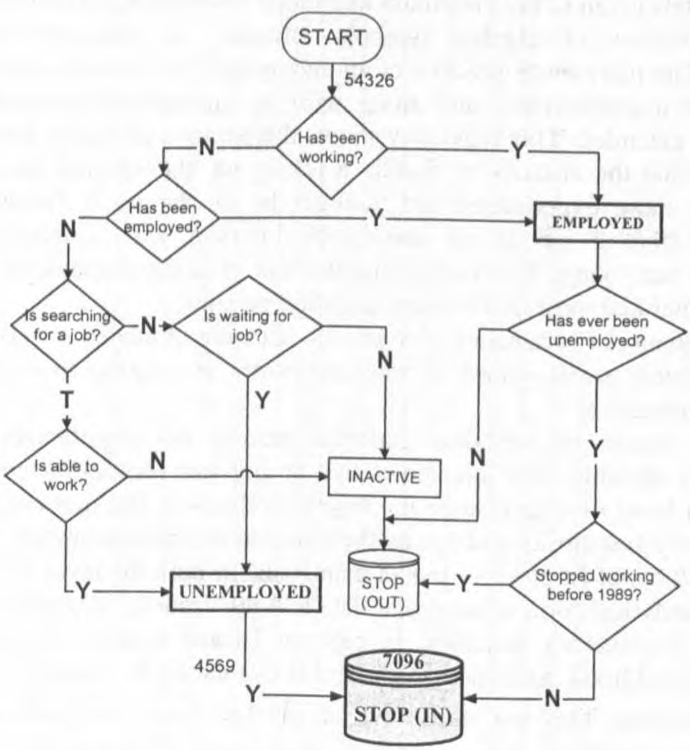
The category "urban" in BAEL control group is desegregated into 7 variants distinguished by the number of inhabitants. The biggest number of the population surveyed lives in cities of over 100 thousand population and the smallest number in those below 5 thousand (also below 2 thousand). From the point of view of distinguished professional activity categories, the most diverse is the population of the biggest cities, and next of the cities with a population of between 5 and 9.999 thousand inhabitants. The least diverse is the population of the smallest cities.

4.3. Technology of filtering the control group

Methodology of survival analysis in the aspect of identification of social and economic determinants with respect to the periods of unemployment requires the division of statistical control group into two separate groups. First of them consists of persons who were out of work in the past, yet, once they got the job, they belonged to ✓ labour forces. The other group is made up of other individuals who (•) either despite the efforts they made remained in ✓ unemployed or (•) are ✓ economically inactive. Using the terminology characteristic of survival analysis they are respectively:

- persons about whom an analyst has complete data set,
- persons about whom an analyst has incomplete data set,
- persons passed over the analysis.

Scheme 1. Technology of filtering BAEL's control group



S o u r c e: Own scheme based on BAEL survey.

The aim of the algorithm of BAEL control group filtration is the selection of individuals affected by unemployment in the real time of the survey (for the critical moment of the observation) or not in the distant past. Classification algorithm of the selection of persons in BAEL's control group is presented in Scheme 1.

5. Empirical hazard models

This study includes estimations of selected hazard models where the following symbols are used:

– explicate variable – t: time of being unemployed (given in months),

– explanatory variable – *practice* (job seniority): total period of working in the last place of work in case of unemployed persons or job seniority in the present workplace in case of employed persons,

– explanatory variable – *age*: age of a person surveyed in the BAEL survey.

The first result breakdown presents estimations of parametric hazard models in their general formula – see Table 1.

The high formal, content-related and methodological note of estimations of hazard models given in the maximum likelihood estimation method consists of:

1° correctness of algebra symbols referring to respected explanatory variables. The increase of practice of an unemployed is accompanied by shorter duration of unemployment and along with an unemployed person's age the duration is extended. This regularity shows the paradox of Polish labour market in a sense that the chances of finding a job by an unemployed person are the bigger, the more experienced and younger he or she is. A Polish employer therefore offers a job to an unemployed person with considerable work experience but young. This means that the risk of being unemployed affects in majority older and most of all worse qualified persons,

2° the quality of parameters of stochastic structure of models is comprised of:

– absolutely small values of standard errors in relation to estimations of relevant parameters,

– high values of t-Student statistics testing the significance of every explanatory variable. The test shows that at any low (bordering on reliability: $p \approx 0.000$) level of significance the true hypothesis is the one concerning the influence of job seniority and age on the duration of unemployment,

3° goodness-of-fit of every model manifested in both the level of the measure of fitting analytical form to empirical data and the accuracy evaluation as for the choice of explanatory variables. In case of hazard models estimated by the maximum likelihood estimation method, this evaluation is made in aggregate by the χ^2 statistics. This test shows that at any low level of significance (nearly reliable: $p \approx 0.000$) the statement that the distinctness of quotation with specified explanatory variables in relation to the hypothetical model where these variables were not included is true.

Table 1. Estimates and statistical characteristics of the parametric models of survival analysis

variable	*beta*	*standard error*	*t-St*	*p*	*variable*	*beta*	*standard error*	*t-St*	*p*	*variable*	*beta*	*standard error*	*t-St*	*p*
normal model[a]					*log-normal model*					*exponential model*				
practice	–2.154	0.054	–39.543	0.000	*practice*	–0.142	0.004	–35.071	0.000	*practice*	–0.175	0.005	–37.073	0.000
age	1.749	0.051	34.429	0.000	*age*	0.114	0.004	30.129	0.000	*age*	0.145	0.005	30.022	0.000
constant	–11.800	1.227	–9.589	0.000	*constant*	0.704	0.091	7.734	0.000	*constant*	0.466	0.115	4.063	0.000
$\chi^2 = 2152.33$; df = 2; p = 0.000					$\chi^2 = 1814.49$; df = 2; p = 0.000					$\chi^2 = 2073.69$; df = 2; p = 0.000				

[a] Broadening of practice (measured by the total job seniority) for the period of one year results in shortening the time of searching for a job by slightly longer than 2 months on average having assumed ceteris paribus. On the same premise, it is expected that the duration of unemployment is extended by nearly 2 months together with another year of the unemployed going by.

S o u r c e: Own calculation based on BAEL's survey.

To recoup: the attributes of presented models are both (•) statistical significance of data which brings in respected independent variables to the description of dependant variable and (•) an adequately good description of the analysed phenomenon (in statistical meaning). Both explanatory variables appear to be "essential" predictors of time during which an unemployed can search for a job and every model "explains" the analysed phenomenon to a satisfactory extent (adequately well).

Further empirical action of the above mentioned hazard model is enriched with an element of quality (factor) diversifying the control group into groups called strata. In the survey, the stratification factors of the control group are sex, place of residence or level of education. This group of Cox's hazard models, called models with stratification, enables carrying out tests to check the consistency of at least two empirical distributions of explanatory variable (duration of unemployment) extracted on the basis of variants of stratification factor. The discriminant of stratification model is separate matching the hazard function for every partial group described by the variants of the respected factor and including the possibility of making an assumption that there are different forms of hazard functions within the stratum. The aim of analysis with stratum is to discover the significant distinctions between distributions of selected groups.

The results of consistency of parametric estimations of hazard models within and without the stratum formula are presented in Table 2.

Table 2. Estimates of hazard models with stratification and without [a]

Model	log-likelihood – total	log-likelihood by groups	χ^2	df	p
stratification by gender					
exponential	−10729.70	−10719.80	19.726	3	0.000194
log-normal	−5327.29	−5315.42	23.752	4	0.000090
normal	−11900.30	−11865.20	70.178	4	0.000000
stratification by place of residence					
exponential	−10729.70	−10699.90	59.644	21	0.000015
log-normal	−5327.29	−5279.47	95.652	28	0.000000
normal	−11900.30	−11844.50	111.490	28	0.000000
stratification by educational level					
exponential	−10721.30	−10567.50	307.475	15	0.000000
log-normal	−5322.39	−5151.83	341.134	20	0.000000
normal	−11889.80	−11685.40	408.908	20	0.000000

[a] Every presented model describes the reality in a better way in the variant with stratification rather than without it. The value of chi-squared statistics of accretion test informs to what extent the model with distinguished strata differs from the model without stratification. The underpinning of hypothesis about the existence of distinctions in the quality of compared models is justified at any low level of significance (p).

S o u r c e: As same as Tab. 1.

The results of the analysis prove that the introduction of factors diversifying unemployed persons according to sex, place of residence or education, improves the Figure of the model phenomenon and the precision of its description. The position of an unemployed person looking for a source of income to the great extent depends on what sex he or she is, where he or she lives and what his or her professional qualifications are. This means that the personalized features of an individual statistically diversify his or her chances of exiting unemployed resources.

Another result breakdown (see Table 3) includes the effect of estimation of Cox's proportional hazard model in general formula (in case of the control group in aggregate).

Table 3. Estimates and statistical characteristics of the Cox's model

variable	*beta*	*standard error*	*t-St*	*exp(beta)*	*p*
practice	0.172	0.005	35.925	1.188	0.000
age	–0.144	0.005	–29.275	0.866	0.000
$\chi^2 = 1951.23$; $df = 2$; $p = 0.000$					

Source: As same as Tab. 1.

The estimated parameters of Cox's model are the risk coefficients which in survival terminology mean occurrence of failure. With respect to the peculiarity of analysed phenomenon, it is a desired state identified with the exit from the unemployed resources to the group employed persons. According to the presented hazard model of duration of unemployment, the chance of changing status quo of an unemployed rises by approximately 18.8% in the circumstances when professional practice improves over 1 year, and every additional year of unemployed person's life has a negative influence on the position on the labour market reducing his or her chance by of getting a job about 13.4%.

Both explanatory variables describing the risk of changing the state of an unemployed (from unemployment to employment) determine it to the great extent and the characteristics of content-related evaluation of the model along with the quality evaluation are fully satisfactory.

7. Summary – evaluation of usefulness of hazard models in the analysis of unemployment

Presented application of the unusual statistic method to the phenomenon of unemployment in Poland brought positive results from the cognitive point of view. Hazard models, which belong to the category of endurance analysis methods, appeared to be an invaluable tool in discovering the nature and identification of time determinants of searching for a job by an unemployed person in conditions of highly unstable labour market. The situation of an unemployed in Poland is highly unfavourable. The reasons for this can be seen, among others, in constantly extending time of being unemployed which results in the lack of financial source of income. From the sociological research it comes out that the poverty and declassification of unemployed are spreading wider and wider.

Some quantitative statistical analyses support sociological research enabling not only identification but also enumeration of determinants of social inequalities caused by bed situation on the labour market. Survival analysis methods represented in the test are superior to standard methods in the sense that they find an application in case when they do not meet basic methodological principles characteristic of popular methods and techniques that model quantitative phenomena. Formal correctness and thorough content-related evaluation of results surpasses the performed analysis, which from the point of view of the objective set in the survey, provides high note of empirical usefulness of modeling techniques and description of such an important social phenomenon like unemployment.

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WYBRANE MODELE HAZARDU W ZASTOSOWANIU DO ANALIZY BEZROBOCIA

Przedmiotem artykułu jest analiza wyników opracowania ankiet pochodzących z Badania Aktywności Ekonomicznej Ludności w Polsce. W oparciu o dostępny zbiór ankiet dokonano charakterystyki osób pozostających bez pracy według tych cech demograficzno-społecznych, które statystycznie istotnie oddziałują na czas pozostawania w zasobie bezrobotnych osób mogących i chcących pracować. Sprawdzono użyteczność wybranych modeli D. R. Coxa do szacowania zależności związanych z ryzykiem długotrwałego pozostawania w zasobie bezrobotnych. Zastosowane w badaniu metody okazały się cennym narzędziem poznania natury i identyfikacji determinant czasu poszukiwania pracy przez bezrobotnego w warunkach wysoce niezrównoważonego rynku pracy.