Institute of Economic Studies, Faculty of Social Sciences
Charles University in Prague

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Petra Kucova
Jana Votapkova

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Institute of Economic Studies,
Faculty of Social Sciences,
Charles University in Prague

[UK FSV – IES]

Opletalova 26
CZ-110 00, Prague
E-mail : ies@fsv.cuni.cz
http://ies.fsv.cuni.cz

Institut ekonomických studií
Fakulta sociálních věd
Univerzita Karlova v Praze

Opletalova 26
110 00 Praha 1

E-mail : ies@fsv.cuni.cz
http://ies.fsv.cuni.cz

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Type 2 Diabetes Mellitus in the Czech Republic: Prevalence and Association with Individual Costs

Petra Kucova[a]
Jana Votapkova[a]

[a]Institute of Economic Studies, Faculty of Social Sciences, Charles University in Prague, Smetanovo nábřeží 6, 111 01 Prague 1, Czech Republic
Email (corresponding author): jana.votapkova@fsv.cuni.cz
Email: petra.kucova@fsv.cuni.cz

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Abstract
The paper examines prevalence of type 2 diabetes mellitus in the Czech Republic based on drug consumption. Data for the whole Czech population for the period 2013-2015 was used to identify patients with diabetes and their health care costs. Association between the presence of diabetes and increased individual health care costs was analyzed: findings from a descriptive analysis (Histograms, Pearson's chi-squared test) were supported parametrically (GLM) for the cohort 55-59 which best allows to separate increased marginal costs incurred by patients suffering from diabetes. Besides, the results suggest that up to one third of diabetic patients in the Czech Republic consume low levels of oral antidiabetics which indicate patient nonadherence to recommended therapy or physician nonadherence to current clinical guidelines.
JEL: I11, I18
Keywords: Type 2 diabetes mellitus; health care costs; histograms; GLM

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Introduction

Chronic diseases are a huge burden both economically and clinically all around the world. Diabetes mellitus is one of the most common chronic diseases: in Europe alone, it is estimated that almost 60 million people suffer from diabetes and the number is expected to exceed 70 million by 2040 (International Diabetes Federation, 2015). In 2011, health expenditures related to diabetes accounted for 6.4 – 13.2 % of the total health expenditures across EU countries (European Commision, 2012). For the Czech Republic, the share of diabetes costs on total health budget is estimated to 8 %.

Type 1 and type 2 diabetes are most common types of diabetes mellitus. Their manifestation – high blood sugar – is similar. However, their nature, cause, and treatment differ: type 1 is an autoimmune disease characterized by inability to produce insulin. The exact cause has not been discovered yet and the treatment relies on receiving insulin from the outside. On the other hand, type 2 diabetes is characterized by insulin resistance – that is when patient's body becomes resistant to insulin and it is no longer used effectively. It is caused by several factors including poor nutrition and physical inactivity and can be, to a large amount, prevented by healthy lifestyle. As many as 90 % of diabetic patients suffer from type 2 diabetes mellitus (International Diabetes Federation, 2015).

Health care costs of diabetes has been analyzed in number of studies (for summary, see systematic reviews compiled by Ng, Lee, Toh, & Ko, 2014 and Seuring, Archangelidi, & Suhrcke, 2015). Methodology employed in the studies varies and depends on the nature of available data. While earlier studies usually identified cost of diabetes for the society in order to quantify the economic burden of the disease, newer research focuses on determining marginal costs of a diabetic patient compared to an individual without diabetes (Ettaro, Songer, Zhang, & Engelgau, 2004).

Recently, disease-specific costs have been often estimated parametrically. By applying advanced econometric techniques, researchers overcome the specific nature of health care data, such as skewed distribution or a substantial number of zero values. Ulrich et al. (2016) quantified direct health care costs of type 2 diabetes patients based on data of 9,160 individuals in Germany finding out that a diabetic costs 1.8 times more than an individual without diabetes. Bruno et al. (2012) analyzed costs in Turin, Italy in 2003-4. Adjusted for age and sex, health care costs in the age group 45-54 years with diabetes (both type 1 and type 2) were 3.8-fold higher than in a group without diabetes. In older age groups, the difference diminishes: 55-64-years-old diabetics revealed 2.8 times higher costs, while diabetics over 74 years incurred 1.7 times higher costs compared to non-diabetics. In Catalonia, Spain, mean annual costs of patients with type 2 diabetes in 2011 were 72.4 % higher than costs of individuals without diabetes as found by Mata-Cases et al. (2016). Nuño-Solinís et al. (2016) analyzed costs of diabetics compared to patients with other chronic diseases in Basque country, Spain, finding out that costs of patients with diabetes were 69% higher than costs of other chronically ill.

Several estimates of costs of diabetic patients in the Czech Republic have been published. Bartášková, Kožnarová, & Kvapil (2005) estimated total costs of diabetes treatment in the

Czech Republic in 2001 to CZK 8.35 billion (EUR 261 million in 2001 exchange rates). This study assigned monetary value to services and medication defined in treatment guidelines, however, did not use real data on health care consumption. Doležal, Písaříková, Zemanová, & Bartášková (2009) calculated health care costs related to diabetes based on health care consumption observed for 495 patients with type 2 diabetes who regularly visit a diabetologist: annual costs amounted to CZK 25,858 per patient. Similar results were obtained by Gajdoš, Juřičková, & Otawova (2015) who analyzed health care data of a random sample of 100 patients with type 2 diabetes. They estimated mean individual costs of a diabetic patient, including drug out-of-pocket expenditure, to CZK 29,531, with median CZK 24,318. High value of standard deviation (CZK 25,055) indicates large variation in distribution of costs (Gajdoš et al., 2015).

Identification of diabetes in published studies in the Czech Republic has so far been based on diagnosis: Institute of Health Information and Statistics of the Czech Republic (IHIS) collects epidemiologic information about selected diagnoses from survey among physicians. Kocová (2015) analyzes claims data from a leading health insurance company, identifying patients with diabetes using diagnoses contained in insurance claims. However, we believe that identification based on diagnosis is quite inaccurate. Return rate and credibility of survey data as employed by IHIS is questionable. On the other hand, diagnoses reported in claims data on outpatient care are not precise either, especially in cases when a patient suffers from several chronic conditions and is treated by a general practitioner. Horák (2009) points out that patients who are treated by general practitioners may not be captured since GPs are reimbursed by capitation and do not have to claim every single examination. On the other hand, doctors in hospitals claim diabetes diagnosis more often, even when it is only suspected (note that there is no rule for claiming suspected diabetes). Furthermore, patients who do not attend her diabetologist for a regular annual check-up are not covered. In addition to Horák (2009), it is reasonable to believe that diagnoses may be miscoded in claims data since they are not subject to any regulation or control mechanism.

According to IHIS (2016), there were 786,586 patients with type 2 diabetes mellitus in 2015 (IHIS, 2016). Unfortunately, they do not publish disease-specific costs and to our knowledge, no population-based study analyzing costs of patients with type 2 diabetes in the Czech Republic has been published, although the issue of diabetes mellitus concerns several national strategies, such as Health 2020 (Ministry of Health, 2014) or National Diabetes Program (Czech Diabetes Society, 2012).

We aim to improve the stream of current Czech research and potentially develop a baseline for a design of an effective strategy to combat the issue of diabetes mellitus. Following Lamers & Van Vliet (2003), we identify diabetics based on their prescribed drug consumption. Also using individual total health care spending reimbursed by health insurance funds in the Czech Republic, we pose the following questions:

(i) What is the number of patients suffering from type 2 diabetes mellitus in the Czech Republic as identified by drug consumption and how did it evolve during the period 2013-2015?

(ii) What is the distribution of diabetics in different age cohorts and sex groups?
(iii) Do Czech data confirm the association between the presence of type 2 diabetes mellitus and increased individual health care costs?

We (i) analyze annual numbers of individuals with type 2 diabetes mellitus in the period 2013-2015. The obtained results are compared to estimates of IHIS which identify patients by reported diagnosis and are thus considered rather problematic. Subsequently, (ii) we analyze prevalence of diabetes in different age cohorts and sex groups using a population pyramid. (iii) The difference between health care costs of patients with diabetes and other insurees in 5-years age groups is compared through histograms and confirmed by Pearson χ^2 test of independence.

The most obvious difference in the distribution of health care costs of diabetics and non-diabetics is observed for 55-69-year-olds. A significant effect of the presence of diabetes on total individual health care costs of the 55-59 year-olds in 2015 is then confirmed also parametrically using a generalized linear model (GLM) similar to Honeycutt, Segel, Hoerger, & Finkelstein (2009). The age group 55-59 in 2015 was chosen as a representative for the parametric analysis because it is the youngest age group with a sufficient number of diabetics for the analysis to be feasible. At the same time, we assume that the younger the person is, the lower is the probability that she suffers from other health problems which drive up the costs biasing the pure effect of diabetes.

Data and Methods

Data

The analysis was conducted from the perspective of a health care payer. Data for the analyses was provided by the Ministry of Health of the Czech Republic. The dataset includes individual-level consumption of all prescribed drugs reimbursed by the health insurance system in the period 2013-2015. In addition, individual-level data on total expenditures on health care was provided. Each individual is characterized by age, gender and the date of death for individuals who died during the period analyzed.

After exclusion of duplicate IDs (4,678 observations in 2013), we ended up with 10,599,989; 10,604,199; and 10,634,193 observations for years 2013, 2014, and 2015, respectively, which represents more than 99.5 % of the population of the Czech Republic.

The descriptive analysis covers the period 2013-2015, the parametric model analyzes the latest available year only.

Identification of patients suffering from type 2 diabetes

Individuals were identified as suffering from type 2 diabetes if they regularly consume oral antidiabetics (Anatomical Therapeutic Chemical group A10B). According to official guidelines issued by the Czech Diabetes Society, all patients diagnosed with type 2 diabetes mellitus should be treated with oral antidiabetics (Škrha et al., 2012). If not explicitly stated

otherwise, throughout the paper, the threshold for consumption was set to 181 of usual daily therapeutic doses (*obvyklá denní terapeutická dávka, ODTD*) per one calendar year, similar to Lamers & Van Vliet (2003).[1] ODTD values set by the State Institute for Drug Control as of July 2016 were employed.

Variables

Costs are expressed in monetary terms. Based on the methodology of the Ministry of Health, medical services are classified into J segments, each with a specific monetary value x_j, where $j = 1, \dots, J$. Total annual health care costs of an individual i, where $i = 1, ...,$ I, are:

$$C_i = \sum_{j=1}^{J} x_j y_{ij} + Z_i \qquad (1)$$

where y_{ij} denotes the number of points for medical services in a segment j consumed by an individual i; x_j represents a monetary value of a point in the j-th segment of care and Z_i stands for health care costs of drugs and medical devices in a calendar year of the individual i, expressed in CZK.

The dummy variable *diabetes* takes the value 1 if an individual is identified as suffering from type 2 diabetes mellitus and zero otherwise. Identification of patients suffering from type 2 diabetes is described above in detail.

Variable *age group* splits the sample of individuals into five-year age intervals for visual inspection (histograms) and a statistical test of independence (Pearson χ^2 test) of costs and the presence of diabetes. Type 2 diabetes mellitus is not an inborn disease, it is rather acquired later in life. Thus, we expect more diabetics among older people.

Variable *sex* is a dummy variable taking the value 1 for males and 0 for females. The sample contains approximately the same number of men and women (Table 1). We expect a positive effect of sex in a GLM regression because Czech men are more often obese than women – among 25-64 year-olds, 25 % of women and 29 % of men are obese (National Institute of Public Health, 2016).

[1] ODTD is a local version of a defined daily dose (DDD) defined by the World Health Organization.

TABLE 1. AGE – DESCRIPTIVE CHARACTERISTICS

	2013	2014	2015
No. of observations	10,599,989	10,604,199	10,634,193
Men	5,226,584	5,229,875	5,250,280
Men (%)	49.3 %	49.3 %	49.4 %
Mean age (standard deviation)	41.4 (22.6)	41.5 (22.7)	41.8 (22.8)

Methodology

Test of independence

To find out independence between two response variables, i.e. cost and the presence of diabetes, we apply the test of independence of distributions in a two-way contingency table which we evaluate by Pearson statistics. The null hypothesis (H_0) of statistical independence between costs and the presence of diabetes equals (Agresti, 2007, p. 36):

$$H_0: \pi_{ij} = \pi_{i\cdot}\pi_{\cdot j} \text{ for all } i \text{ and } j \qquad (2)$$

where π_{ij} is a joint probability of occurrence in a contingency table and $\pi_{i\cdot}$ and $\pi_{\cdot j}$ are marginal probabilities.

Pearson statistics for testing H_0 of independence in $I \times J$ contingency tables is (Agresti, 2007):

$$\chi^2 = \sum \frac{(n_{ij} - \hat{\mu}_{ij})^2}{\hat{\mu}_{ij}} \qquad (3)$$

where n_{ij} is a sample proportion of each cell and $\hat{\mu}_{ij} = n\pi_{ij} = n\pi_{i\cdot}\pi_{\cdot j}$ is the estimate of expected frequencies. Unknown marginal probabilities $\pi_{i\cdot}$ and $\pi_{\cdot j}$ in the estimate of expected frequencies are substituted by the observed sample proportions $n_{i\cdot}$ and $n_{\cdot j}$ such that

$$\hat{\mu}_{ij} = n\left(\frac{n_{i\cdot}}{n}\right)\left(\frac{n_{\cdot j}}{n}\right) = \left(\frac{n_{i\cdot}n_{\cdot j}}{n}\right) \qquad (4)$$

In other words, the row total of the cell is multiplied by a column total of the cell, divided by the overall sample size.

The resulting χ^2 distribution has $(I-1)(J-1)$ degrees of freedom.

Generalized linear model

Data on health care costs are characterized by a substantial number of zero values (i.e. part of the population did not incur any costs during the study period) on one hand, and on the other hand, costs of those who do incur some costs are usually skewed to right (Manning, 2012). In the parametric analysis, we therefore employ a generalized linear model (GLM) with gamma

distribution and log link, $g(\mu) = \log \mu$.[2] This model has been often applied to estimate the costs of diabetes (Bruno et al., 2012; Honeycutt et al., 2009; Mata-Cases et al., 2016; Pagano et al., 2016).

The GLM model with a gamma distribution and a log link to estimate the level of health care spending takes the following form (Honeycutt et al., 2009, p. 307):

$$E(y_i) = e^{x_i \beta_i}, \qquad y \sim \text{Gamma} \qquad (5)$$

where y_i represents total annual health care costs of an individual i in the year 2015. Matrix x_i includes two dummy variables identifying the presence of diabetes and sex. The final standard errors of the model are robust to autocorrelation and heteroscedasticity. Optimization is done through maximum-likelihood.

The model was estimated only for the 55-59 age group as a representative since it is the youngest age group with enough diabetics for the analysis to be feasible. At the same time, this age cohort is considered to be young enough not to suffer from too many other health problems besides diabetes which would drive up costs. Given the large share of the cost of diabetes on the total health care costs of national economies in aggregate, we assume that the presence of diabetes will exert a significant positive effect on total health care costs of an individual as well.

The econometric analysis is expected to supplement and support the results obtained in the descriptive analysis. However, besides associations between the presence of diabetes and annual medical costs of an individual, other qualified inference from the results is hampered due to missing variables.

Results

Descriptive data analysis

The total number of patients with type 2 diabetes as identified by a minimum consumption of 181 ODTD of oral antidiabetics per year does not even reach 380 000 cases annually. Compared to IHIS (2016), the difference in number of patients with type 2 diabetes is more than 410 000 cases (see Table 2). Note that IHIS identifies diabetic patients based on the number of patients with the diagnosis of type 2 diabetes mellitus reported by physicians. Therefore, we also analyzed the number of patients defined by two alternative definitions: patients with at least 91 ODTD – an alternative threshold used by Lamers & Van Vliet (2003) – and patients with any amount of consumed oral antidiabetics to capture patients with low levels of prescribed oral antidiabetics. Results are shown in Table 2 (note that these figures show numbers as of the end of each year, i.e. patients who died during the year are not included).

[2] Note that in our case, by definition, μ cannot be negative, the distribution is skewed to the right and variation increases with the mean.

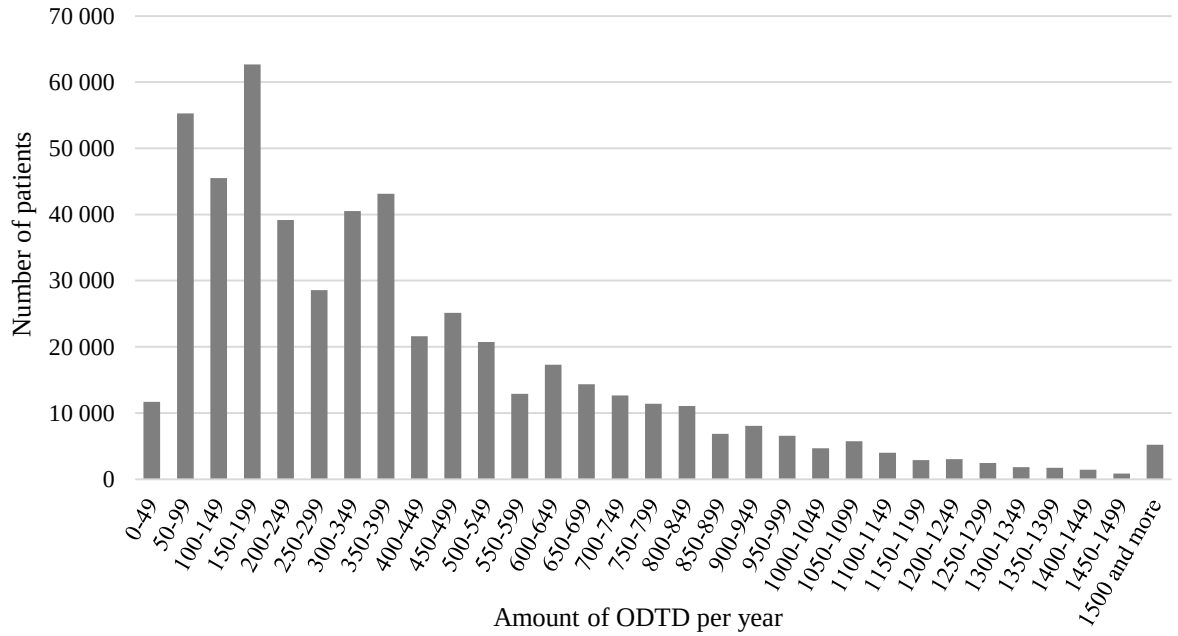
TABLE 2. NUMBER OF PATIENTS TREATED BY ORAL ANTIDIABETICS IN 2013-2015 IN COMPARISON WITH IHIS DATA

	≥ 181 ODTD per year		≥ 91 ODTD per year		> 0 ODTD per year		IHIS (2016)
	Total number	Number of new cases	Total number	Number of new cases	Total number	Number of new cases	Total number
2013	330,399		436,112		533,357		789,900
2014	357,788	77,174	475,179	91,190	583,329	102,069	788,243
2015	374,959	67,681	495,674	75,673	606,125	78,643	786,586

The number of patients treated by oral antidiabetics have risen regardless of a threshold. Between 2013 and 2015, the share of patients with diabetes in the total population grew by 13 %. Note that according to official guidelines for treatment of diabetes everyone diagnosed with type 2 diabetes should take oral antidiabetics (Škrha et al., 2012). Therefore, the number of new cases include both newly diagnosed individuals and diabetics who started taking oral antidiabetics, i.e. those previously not treated according to the recommended guidelines. Our results suggest that not all physicians strictly adhere to the guidelines, though the number of physicians following guidelines is expected to increase over time.

Figure 1 shows the distribution of patients by the amount of consumed ODTD per year in 2015. To exclude new cases, only patients with positive consumption of oral antidiabetics in 2014 were included. Patients who died during the year were excluded. Results show that one third (33.4 %) of patients with consumption of oral antidiabetics in the previous year consumed less than 181 ODTD per year in 2015, and do not exceed the threshold for identification of patient with diabetes as recommended by Lamers & Van Vliet (2003). Czech official guidelines for treatment of type 2 diabetes mellitus recommends a dose of 0.25 – 0.5 ODTD per day at the beginning of the therapy with gradual intensification in line with individual tolerance. Maximum dose is set to 1.5 ODTD per day, chronic maintenance dose usually does not exceed 1 ODTD per day (Škrha et al., 2012). Therefore, a patient treated in compliance with current guidelines who is not at the beginning of the therapy should consume up to 365 ODTD per year. Our data suggests that a substantial part of diabetic patients take less than 0.5 ODTD per day and thus might be undertreated; however, we are not able to distinguish whether physicians do not prescribe appropriate amounts of antidiabetics or whether patients do not pick up prescribed drugs in the pharmacy. On the other hand, results also show that 22.9 % of identified patients collected more than 547.5 ODTD per year which corresponds to annual amount of maximum recommended dose. Even if we take into consideration that patients might collect some drugs to stockpile, certain part of patients collected extreme amounts of drugs: 10.1 % of patients collected more than 821.25 ODTD in one year which corresponds to the maximum daily dose for one and a half years. If collected medication is also consumed by the patient themselves, these patients are overtreated. This assumption, however, is too strong: some prescribed and collected drugs may not be consumed or may be consumed by a different patient than the one who is indicated in the data.

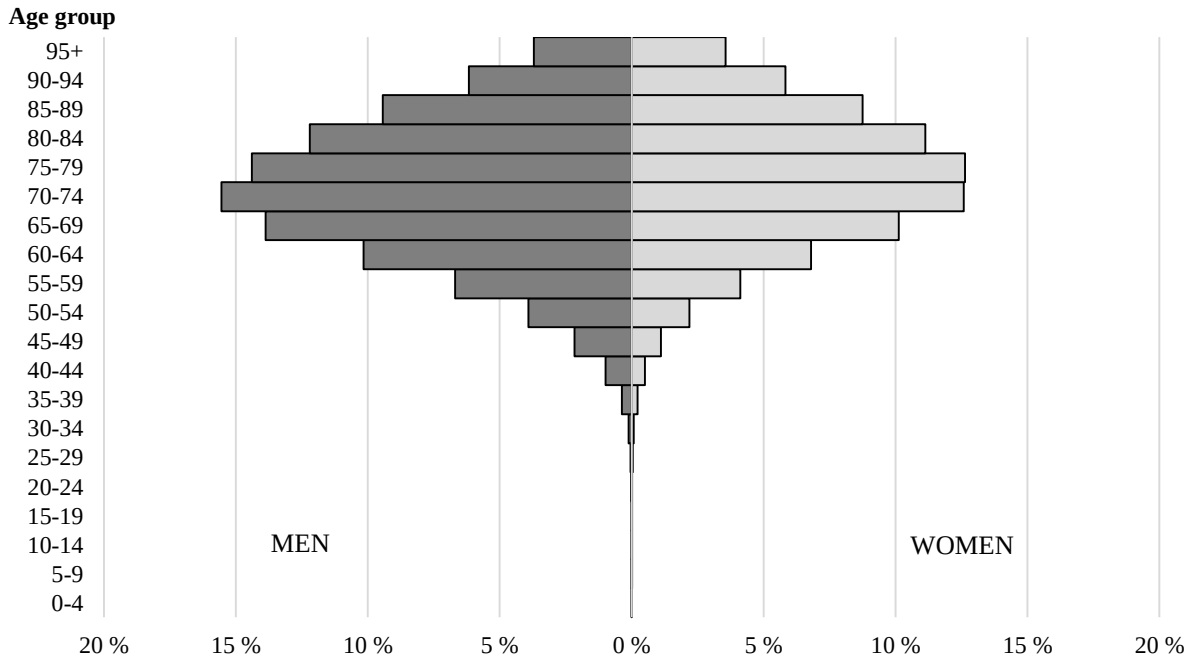
FIGURE 1. NUMBER OF PATIENTS WITH DIABETES BY AMOUNT OF ODTD PER YEAR (2015)



Note: Only patients with some consumption of oral antidiabetics in the previous year (2014) were included

Figure 2 shows the share of patients with diabetes in 5-years age groups by sex. Not surprisingly, higher prevalence of type 2 diabetes is observed among older patients. Men suffer from diabetes more often than women which can be explained by fewer risk factors observed among women. Czech women are less obese (30.5 % vs. 43.3 %) and overweight than men (24.7 % vs. 29.1 %), eat healthier food and smoke less (30.7 % of women are smokers vs. 32.4 % of men) (National Institute of Public Health, 2016). The highest prevalence of diabetes is in ages 70-79: for men, the peak is age group 70-74 years where 15.5 % of all men in this group suffer from diabetes, while for women, the age group with the highest prevalence is 74-79 years (prevalence 12.6 %). Our results confirm findings by Kocová (2015) who analyzed age structure of patients with diabetes using data from the General Health Insurance Company.

FIGURE 2. AGE STRUCTURE OF PATIENTS WITH DIABETES BY GENDER (2015)



Type 2 diabetes mellitus is an incurable disease, therefore, once diagnosed, a patient suffers from it for the rest of her life. In absolute value, most diabetics are between 65-69 years old (data not shown). Declining number of diabetics among older people indicates that patients with diabetes die prematurely, which is observed all around the world (International Diabetes Federation, 2015).

Costs of diabetics consuming more than 181 ODTD of oral antidiabetics per year vs. non-diabetics in two different age groups are analyzed through histograms in Figure 3, additional figures are available in Appendix 1. The number of observations that fall into 1,000 CZK bins form a function *m* that is plotted against its density. In age groups younger than 35 years, the prevalence of diabetes is too low for an analysis (1–736 cases with diabetes in each group in contrast with 461,706–718,625 individuals without diabetes). However, for 35-39-year-olds, the difference in the distribution of costs is already observed: while mean costs for patients with diabetes are almost three times higher than mean value for non-diabetics (CZK 36,798 vs CZK 13,773), the difference in median is much larger: CZK 22,667 for patients with diabetes versus CZK 4,392 for individuals without diabetes (see Table 3). Similar patterns are observed in other older age groups, however, the proportion of individuals with low costs within the group of individuals without diabetes decreases and the difference diminishes. This indicates that with increasing age individuals suffer from other health issues and diabetes is not the main driver of costs.

FIGURE 3. COMPARISON OF DISTRIBUTION OF COSTS OF PATIENTS WITH DIABETES AND WITHOUT DIABETES IN SELECTED AGE GROUPS

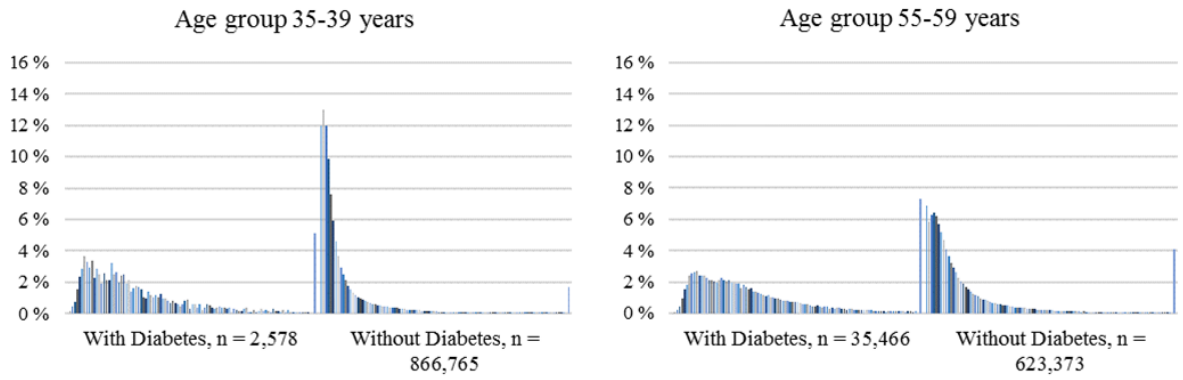


TABLE 3. DESCRIPTIVE STATISTICS OF COSTS IN AGE GROUP 35-39 YEARS

	Mean	Median	0.25 percentile	0.75 percentile
With diabetes	36,798	22,667	12,371	39,761
Without diabetes	13,773	4,392	2,002	10,455

Pearson χ^2 test of independence confirms results of a graphical analysis that costs and the presence of diabetes are associated. Test results are shown in Table 4. The test could not be performed for two youngest age groups (0-4 years and 5-9 years) because of a low number of observations with diabetes. For other age groups, the test rejected the null hypothesis of independence between costs and occurrence of diabetes, with the strongest result obtained for ages 55-69. It suggests that for older people, diabetes is not the main driver of costs. The only exception is the oldest age group (95+) for which the null hypothesis of independence was not rejected; nevertheless, the prevalence of diabetes in this age group is 3.6 %, compared to 5.9 % in the 90-95 age group. We assume that patients with diabetes who are older than 95 years are comparatively healthier than other diabetics as they have reached such a high age.

TABLE 4. PEARSON X^2 TEST OF INDEPENDENCE – RESULTS

Age group	Pearson χ^2 test	Simulated P-value (2000 replicates)	No. obs.
0-4	NA		1
5-9	NA		2
10-14	316	0.000	11
15-19	826	0.000	34
20-24	1,022	0.000	52
25-29	1,259	0.000	80
30-35	1,594	0.000	121
35-39	5,118	0.000	148
40-44	14,997	0.000	192
45-49	17,845	0.000	194
50-54	29,163	0.000	200
55-59	32,180	0.000	200
60-64	40,798	0.000	200
65-69	40,521	0.000	201
70-75	20,892	0.000	200
75-79	8,710	0.000	200
80-84	3,430	0.000	199
85-89	1,536	0.000	199
90-95	375	0.000	192
95+	120	0.150	104

Parametric analysis

Generalized linear model (GLM) regression with gamma distribution and log link was carried out on a group of individuals 55-59-year-old. The age group 55-59 was chosen as a representative of a group with a particularly strong dependence between costs and the presence of diabetes found in the descriptive analysis. In addition, this age group reports a significant number of diabetics compared to younger cohorts and at the same time is considered to be still young enough not to suffer additional health issues besides diabetes that drive up costs. Results robust to heteroscedasticity and autocorrelation[3] are provided in Table 5.

Parametric GLM regression merely reports associations between the presence of diabetes and annual health care costs of an individual and thus supports the descriptive and graphical analyses. The number of explanatory variables is rather limited and thus also explanatory power of the model is weak (AIC = 22.36082, BIC = –7514898). There is no doubt that besides sex and the presence of diabetes there are other variables influencing health care costs of patients, these are however not available.

The results in Table 5 confirm that the effect of the presence of diabetes on costs is strongly positive and significant. With available data and ceteris paribus, it suggests that a presence of

[3] Under homoscedasticity, the robust standard errors become just conventional standard errors, thus robust standard errors are appropriate even under homoscedasticity.

type 2 diabetes causes a 80% increase in annual health care costs relative to non-diabetics among 55-59 year-olds.[4] By the same token, Table 5 suggests that in this age group, males cost the health care system approximately 1.017 times more than women.

TABLE 5. GENERALIZED LINEAR MODEL RESULTS

Costs	Coef.	Robust Std. Err.	z	P > |z|	95% Conf. Interval	
Sex[a]	0.0167714	0.008774	1.91	0.056	-0.0004254	.0339681
Diabetes	0.5870047	0.0119167	49.26	0.000	0.5636483	.610361
_cons	10.14042	0.0056561	1792.82	0.000	10.12934	10.15151

[a] Variable *Sex* takes the value 1 for men and 0 for women.

Discussion and conclusions

Diabetes is one of the most common chronic diseases worldwide. The aim of this study was to (i) analyze the number of patients with type 2 diabetes mellitus in the Czech Republic using population data, and (ii) shed light on association between health care costs and the presence of diabetes in the Czech Republic. Using the dataset of medicine consumption and health care costs of the whole population in the period 2013-2015, patients with diabetes were identified based on the consumption of oral antidiabetic drugs. Since pharmacotherapy for patients with diabetes should be initiated immediately after the diagnosis is confirmed (Škrha et al., 2012), we believe that this approach is more precise than identification of patients based on a reported diagnosis. The number of diabetics identified through chronic medication was significantly lower than the figure reached by the IHIS based on a reported diagnosis: we identified 374,959 individuals with at least 181 ODTD per year in 2015, while IHIS reports 786,586 patients with type 2 diabetes mellitus as reported by a physician (IHIS, 2016). However, 10.7 % of patients reported by IHIS (IHIS, 2016) are treated by a diet only (in contradiction to current guidelines). The remaining difference may stem from a different methodology of data collection: while IHIS figures rely on survey among physicians and extrapolate collected data on the whole population (return rate in 2015 was 77 %), our analysis use actual medicine consumption and does not cover non-adherent patients (i.e. those who do not collect prescribed medicine in the pharmacy) and recently diagnosed patients who are beginning their pharmacotherapy.

The analysis of individual annual consumption of ODTD suggest that substantial part of patients (up to one third of identified cases) is undertreated. Unfortunately, the cause – whether physicians do not follow guidelines for treatment and prescribe low amount of medicines, or whether patients do not follow their treatment and do not pick up the drugs in the pharmacy – remains unknown. Anyway, this finding may have potentially important implications as the introduction of chronic condition parameter retrieved from drug consumption is expected to be employed in redistribution scheme for allocation of funds among health insurance companies in the Czech Republic in the future.[5] Patients who do not

[4] $(\exp(0.5870047) - 1 \cong 0.80)$.

[5] At the time of writing, the amendment introducing new redistribution scheme was being discussed in the Senate. It is expected to come into effect from January 1, 2018.

consume specified amount of drugs (threshold of 181 ODTD is expected to be used in the redistribution model) will not be classified as chronically ill and their insurance company will not receive extra funds as a compensation for the risk of increased costs incurred by these patients. Taking into account higher costs incurred by patients with diabetes in general (International Diabetes Federation, 2015), health insurance companies should require that their insurees diagnosed with diabetes consume adequate levels of chronic medication – positive effect of pharmacotherapy for type 2 diabetes mellitus is undoubted and it is recommended in national as well as foreign respected guidelines (American Diabetes Association, 2017; Škrha, Pelikánová, & Kvapil, 2016). Health insurance companies should employ strategies to promote adherence both among patients and physicians, such as information campaigns and education for patients and clinical pathways distributed to physicians. On the other hand, our results suggest that there are patients who consume (or rather collect) extreme amounts of oral antidiabetics. These should be of a concern of a control mechanism of health insurance companies, since they may raise costs with no clinical relevance.

Type 2 diabetes mellitus occurs mainly among older population. The analysis reveals a significant difference in costs between the group of patients with and without diabetes for people older than 35 years with the exception of the oldest age group (95+). The strongest difference, as obtained both by histograms and Pearson χ^2 test of independence, is observed for ages 50-64. In older cohorts, other health problems are likely to occur and the difference in health care costs between diabetics and non-diabetics diminishes. A parametric analysis, which however merely supplements the descriptive part of the paper, also points out to an existing association between costs and the presence of diabetes in Czech population. By the same token, men cost the system more than women, ceteris paribus.

Limitation of the study

Despite new findings, the paper suffers from a few limitations that stem primarily from the nature of the data available.

First, the descriptive and parametric analyses employed in the paper cannot technically separate marginal costs incurred by diabetes and other diseases, as opposed to other methods (e.g. attributable fraction approach or bottom-up approach). After all, separation of marginal costs caused by diabetes and other diseases was not the purpose of this paper. We, however assume that the group of 55-59 year-olds – which is the youngest age cohort for which a parametric analysis is technically feasible due to the number of observations classified as diabetics – is still young enough not to extensively suffer from additional diseases which usually cause a rapid cost increase. Such an approach enabled us to separate marginal costs of diabetes even within descriptive and parametric analyses. The association between costs and the presence of diabetes is thus considered sufficiently convincing.

Second, except for the association between costs and the presence of diabetes, any inference from the parametric analysis can unfortunately be made due to unavailable data. Other variables, such as marital status, economic situation, educational level, etc. used in other cost-of-illness studies to control for observable factors undoubtedly explain variation in annual

health care costs of an individual (American Diabetes Organization, 2013). In addition, these other covariates would enable us to carry out a matched control regression as recommended by Akobundu, Ju, Blatt, & Mullins (2006). Note that even health insurance companies which are responsible for premium collection do not have information about individual wages and socioeconomic variables of an individual.

Third, variables controlling for diabetic complications and comorbidities may improve the regression results as recommended by Larg & Moss (2011). Nevertheless, identifying different stages of diabetes progression goes beyond the scope of this study and need robust and validated definitions for specific conditions which cannot be distinguished from drug consumption only. This serves as motivation for further research.

Finally, further research may also investigate interactions of type 2 diabetes and other medical conditions as retrieved from drug consumption data, similar to Lamers & Van Vliet (2003).

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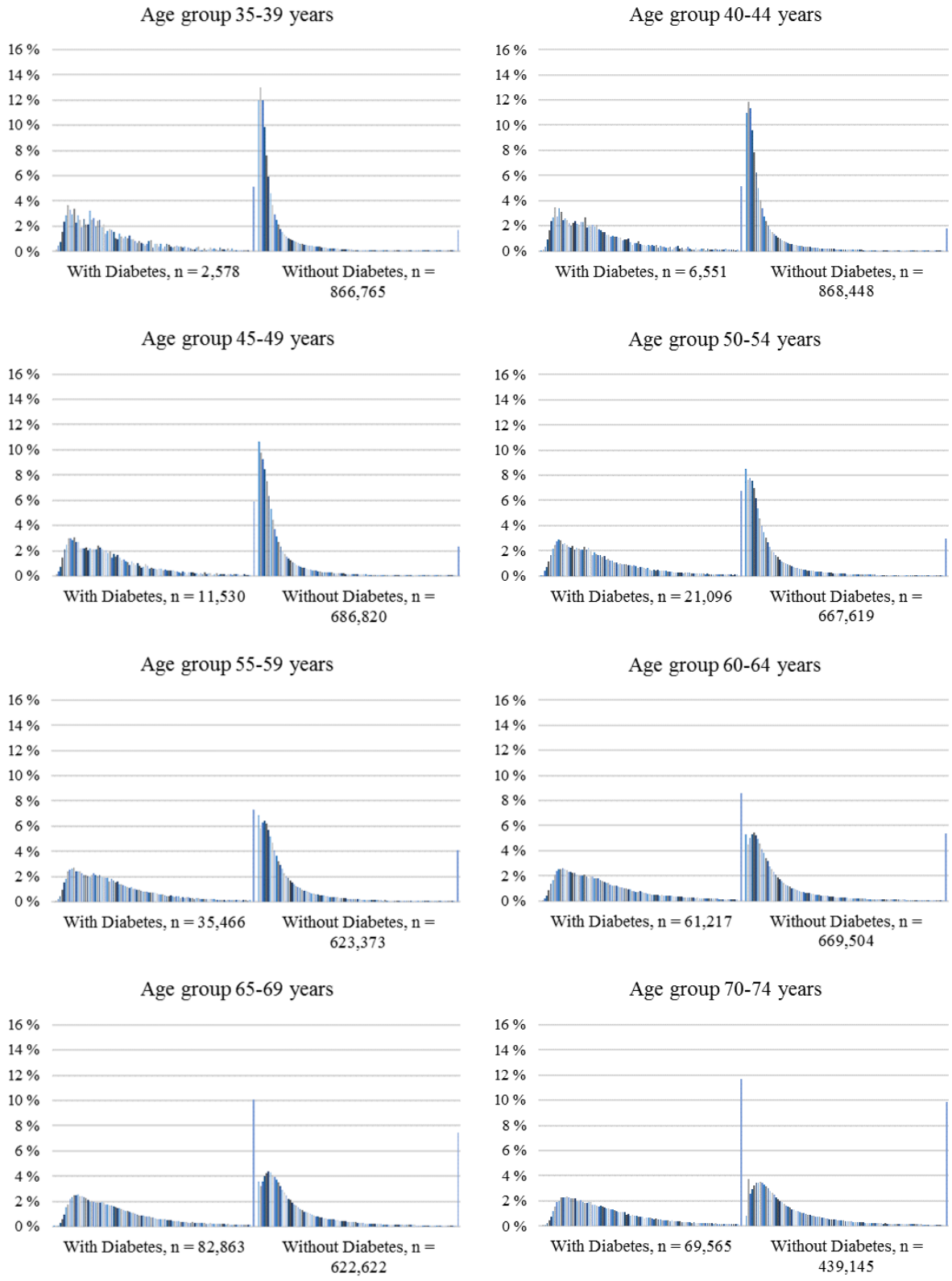
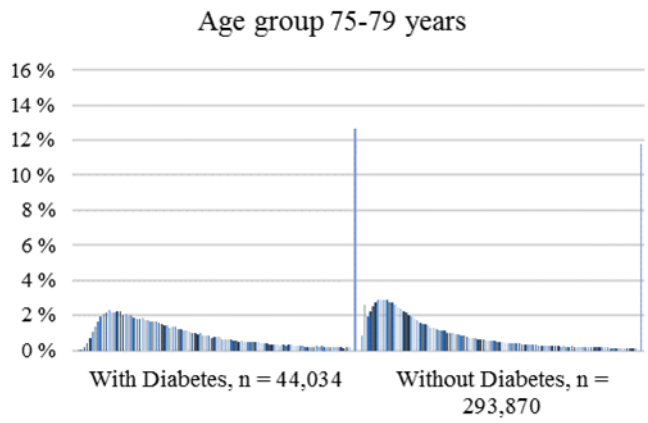
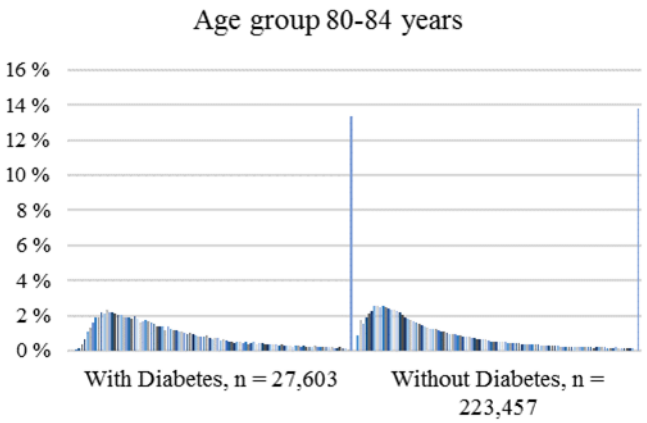
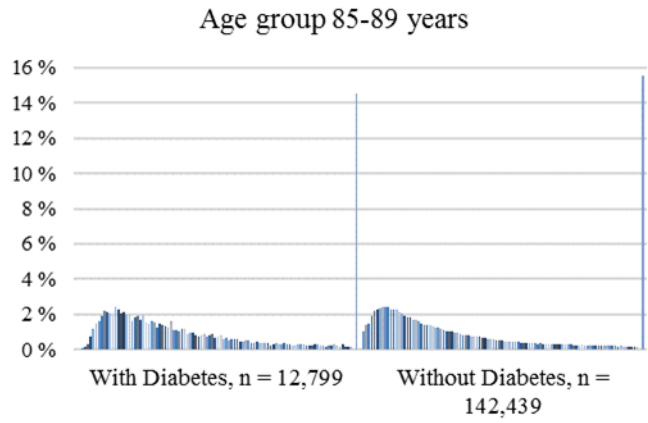
Appendices

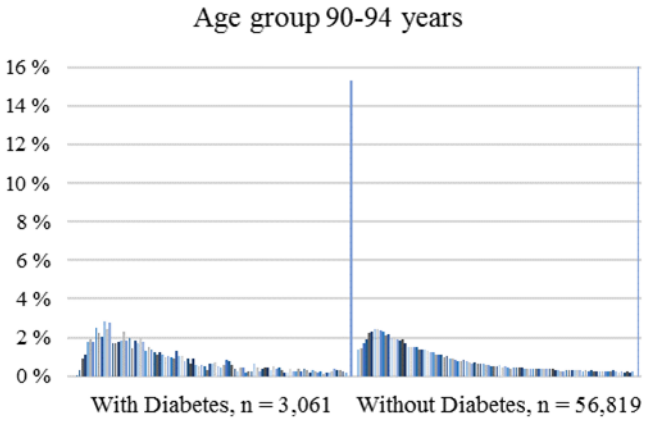
Appendix 1. Distribution of costs by age groups, histograms (2015)

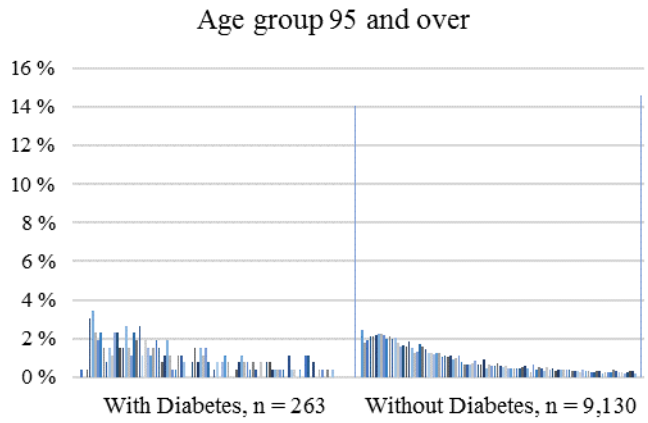



Age group 75-79 years
16 %
14 %
12 %
10 %
8 %
6 %
4 %
2 %
0 %
With Diabetes, n = 44,034
Without Diabetes, n = 293,870


Age group 80-84 years
16 %
14 %
12 %
10 %
8 %
6 %
4 %
2 %
0 %
With Diabetes, n = 27,603
Without Diabetes, n = 223,457


Age group 85-89 years
16 %
14 %
12 %
10 %
8 %
6 %
4 %
2 %
0 %
With Diabetes, n = 12,799
Without Diabetes, n = 142,439


Age group 90-94 years
16 %
14 %
12 %
10 %
8 %
6 %
4 %
2 %
0 %
With Diabetes, n = 3,061
Without Diabetes, n = 56,819


Age group 95 and over
16 %
14 %
12 %
10 %
8 %
6 %
4 %
2 %
0 %
With Diabetes, n = 263
Without Diabetes, n = 9,130

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Univerzita Karlova v Praze, Fakulta sociálních věd
Institut ekonomických studií [UK FSV – IES] Praha 1, Opletalova 26
E-mail : ies@fsv.cuni.cz http://ies.fsv.cuni.cz