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Original Article

Identifying Influential Variables on Health Expenditure of the Organisation for Economic Co-Operation and Development (OECD) Countries

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Abstract

Background: Health expenditures of countries have an increasing trend in general and identifying variables affecting health expenditure is an important step toward budget planning for financial sustainability. This study aimed to examine the health expenditure of the Organisation for Economic Co-operation and Development (OECD) countries and identify influential variables.

Methods: The data for the years 2000-2018 of OECD countries' current health expenditure (% of GDP) and economic, demographic, and health variables, considered to affect the health expenditure, to include in the analysis were extracted using the World Bank database (World Bank 2021). Data analys using Chi-Squared Automatic Interaction Detection (CHAID) decision tree technique. Fifteen variables in economic, demographic, and health categories are selected to build the CHAID decision tree.

Results: As a result of CHAID analysis, five variables are identified as influential on current health expenditure, which are gross domestic product per capita, life expectancy at birth, death rate, out-of-pocket expenditure, and fertility rate. Thirty-seven OECD countries are classified into eleven groups by the decision rules in terms of the current health expenditure. The high value of the correlation coefficient between the predicted values and the actual values of health expenditure of countries indicates good prediction performance. Moreover, the regression models built using the identified influential variables as explanatory variables give good forecast accuracy.

Conclusion: As an effective tool, the CHAID decision tree technique provides a rule-based model in the form of a tree with nodes and branches, illustrating the splitting process graphically with identified variables and their cut-off points for classification and prediction.

Keywords: CHAID decision tree; Regression; Health expenditure

Introduction

Countries' spending on health can be measured by health expenditure as a share of the Gross Domestic Product (GDP). The Organisation for Economic Co-operation and Development (OECD) countries have spent on average 8.8% of GDP on

health care between 2013 and 2018, whereas on a country-by-country basis there are differences in the health-to-GDP ratio due to various factors, such as economic conditions and policies on health care (1). Health expenditure is considered one of the most essential economic issues for all countries, regardless of their income level-high, medium, or low, as in most countries the main funding source of health expenditure is public sources. Therefore, identifying influential variables on health expenditure can contribute to making accurate projections for health spending and hence help policymakers to use these projections in financial planning.

Understanding the relationship between macroeconomic variables and countries' health expenditures helps policymakers make long-term decisions (2). In this study, demographic, economic, and health variables are selected to examine their effects on the health expenditure of OECD countries using the Chi-Squared Automatic Interaction Detection (CHAID) decision tree technique. CHAID decision tree for the year 2015. To evaluate the success of the CHAID decision tree technique, regression models are built using identified influential variables as explanatory variables and health expenditure as the dependent variable for the years 2000-2015, and then predictions are made and compared with actual values for the years 2016-2018.

In the literature, various studies explain the effects of the factors on health expenditure. The main affecting factors are summarized as GDP per capita (3), demography, life expectancy (4, 5), inflation (6), income growth (7), age groups (8), aging population (2, 9-11), morbidity (12) and technological progress (13,14).

The health expenditures of countries will continue to increase. The economic performance of the countries is defined as the main indicator of health expenditure. In many countries, health expenditure is increasing faster than GDP and much research indicates that there is a strong relationship between health expenditure and the GDP of the countries (15) GDP is identified as a major economic determinant of health expenditure (2, 3, 6, 16,17). Gerdtham and Lothgren (16) apply both country-by-country and panel tests using OECD countries data for the period 1967-1997 and show that GDP and health expenditure are cointegrated. Awais et al. (2) show based on the panel data analysis that GDP is a significant determinant of health expenditure in developed countries and has a positive impact. Atalan and Donmez (18) use GDP in the multi-objective optimization models as one of the variables explaining the variability in the health expenditures of OECD countries. Current dollar health expenditure in the short run, real health expenditure per capita in the medium run, and the share of GDP in the long run, are the best measures of health spending to forecast (6).

Out-of-pocket expenditure is one of the components of health expenditure. The percentage of out-of-pocket expenditure in health expenditure has decreased from 19.4% in 2000 to 18.2 in 2015 worldwide (19). Out-of-pocket expenditure is found as a significant variable increasing health expenditure of both OECD and Asian countries and when the two country groups are compared, the size of the impact for OECD economies is approximately three times greater than that of Asian economies (20). Out-of-pocket expenditure is a major source of health care financing in developing countries (21).

There are studies examining whether demographic variables such as the aging population, population growth, and fertility rates have an impact on health expenditures. The aging population is one of the major concerns of the governments regarding health care financing. Lee and Miller (3) forecast health expenditure accounting for the uncertainty of mortality, fertility, and health spending per capita in the United States. Age dependency ratio is indicated as a significant variable of health expenditure as a result of decision tree analysis (17). Population growth is considered one of the factors affecting health expenditure, as it enables more people potentially use health services (11). Uncertainty about the fertility rate due to its growing effect on the labor force size significantly affects uncertainty about health expenditure (3).

Life expectancy at birth is positively related to health expenditure as it increases the share of the elderly population (2). Life expectancy at birth is

identified as a significant determinant of health expenditure by many researchers (2, 4, 5, 17, 18, 20, 22, 23, 24). The decision tree analysis indicates that perceived health status and the number of hospitals in OECD countries are significant health-related variables for health expenditure (17).

The most common decision tree techniques are Classification And Regression Tree (CART), C5.0, and CHAID (25). Decision tree techniques are rarely used in health-related studies. Chan et al. (26) examine service and demographic variables' effects on employment outcomes of vocational rehabilitation clients by CHAID analysis, Giudici et al. (27) predict the health status based on important variables using CART, Akca et al. (11) use the CART decision tree to identify determinants of health expenditure, Karacan et al. (28) use the CHAID decision tree for the analysis of life expectancy. The decision tree technique is considered one of the most useful data mining methods, owing to discretizing continuous variables into classes, not being affected by the presence of outliers, handling the missing data, heterogeneous data, and non-linear data, being a non-parametric method, producing easily understood results, and forming the classification model with the set of rules (25).

We aimed to examine the health expenditure of OECD countries and identify influential variables using CHAID decision tree technique.

Materials and Methods

Current health expenditure is taken into account. Current health expenditure is defined as the total amount of money consumed on health services and products, excluding machinery, information technology, buildings, and vaccine stocks for each year, formed in currency in a country or region (19).

The methods used in this study are CHAID decision tree technique and regression. The influential variables on health expenditure of OECD countries are identified using CHAID decision tree technique. In order to evaluate the success of the technique, the regression models are built using influential variables and health expenditures of OECD countries are forecasted.

CHAID decision tree has the root node at the top, which has only child nodes. The root node is split into branch nodes, which have a parent node and several child nodes, by the best splitting variable identified based on the Chi-square test and corresponding *P*-value. The Chi-square test is applied to define the most significant variable of each node with respect to the dependent variable and the procedure continues iteratively until there are no splits to make or no variables left, or a prespecified number of branch levels is achieved hence, leaf nodes are formed through identified variables and their cut-off points. Leaf nodes have only a parent node. The path between the root node and each leaf node gives the decision rule for the classification.

The regression equation used to find models for OECD countries is given in Eq.1. The best subset regression is applied using influential variables as explanatory variables to select the best regression model for each OECD country.

$$Y = \beta_0 + \beta_1 X_1 + \cdots + \beta_k X_k + \varepsilon \quad [1]$$

The forecasting accuracy is calculated using Mean Absolute Percentage Error (MAPE) (Eq. 2).

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}\left|\left(\frac{Y_t - F_t}{Y_t}\right)\times 100\right| \quad [2]$$

The methodology of the study is summarized by the following steps:

1. Extract data for current health expenditure and related economic, demographic, and health variables
2. Apply the CHAID technique
3. Identify influential variables on current health expenditure
4. Apply best subset regression for each OECD country to the training set using influential variables as explanatory variables
5. Select the best model for each OECD country
6. Fit the selected regression model to the training set
7. Obtain forecasts for each OECD country

8. Calculate forecasting errors by MAPE on the test set

The data for the years 2000-2018 of OECD countries' current health expenditure (% of GDP) and economic, demographic, and health variables, considered to affect the health expenditure, to include in the analysis were extracted using the World Bank database (World Bank 2021). The 2015 year data were used to build the CHAID decision tree. To evaluate the prediction performance of the identified influential variables on current health expenditure, regression models were built. The data for the years 2000-2015 were used as the training set and 2016-2018 as the test set.

Thirty-seven OECD countries included in the study are Australia (AUS), Austria (AUT), Belgium (BEL), Canada (CAN), Chile (CHL), Colombia (COL), Czech Republic (CZE), Denmark (DNK), Estonia (EST), Finland (FIN), France (FRA), Germany (DEU), Greece (GRC), Hungary (HUN), Iceland (ISL), Ireland (IRL), Israel (ISR), Italy (ITA), Japan (JPN), Korea, Rep. (KOR), Latvia (LVA), Lithuania (LTU), Luxembourg (LUX), Mexico (MEX), Netherlands (NLD), New Zealand (NZL), Norway (NOR), Poland (POL), Portugal (PRT), Slovak Republic (SVK), Slovenia (SVN), Spain (ESP), Sweden (SWE), Switzerland (CHE), Turkey (TUR), United Kingdom (GBR), and United States (USA). The dependent variable is current health expenditure (% of GDP). Economic, demographic, and health variables included in the analysis are given in Table 1.

Table 1: Variables used in CHAID analysis

Category	*Variable*	*Label*
Dependent Variable	Current health expenditure (% of GDP)	CHEP
Economic Variables	Out-of-pocket expenditure (% of current health expenditure)	OOPEP
	GDP growth (annual %)	GDPGP
	Inflation, GDP deflator (annual %)	INFD
	GDP per capita (current US$)	GDPCD
	Research and development expenditure (% of GDP)	RDEGDP
Demographic Variables	Age dependency ratio (% of working-age population)	ADR
	Population, total	PT
	Population growth (annual %)	PG
	Death rate, crude (per 1,000 people)	DR
	Fertility rate, total (births per woman)	FR
	Birth rate, crude (per 1,000 people)	BR
Health Variables	Hospital beds (per 1,000 people)	HB
	Physicians (per 1,000 people)	PH
	People using safely managed sanitation services (% of population)	SS
	Life expectancy at birth, total (years)	LIFEX

Results

Based on the CHAID decision tree in Fig.1, among fifteen variables analyzed, five variables are identified as influential on current health expenditure which are GDP per capita, life expectancy at birth, death rate, out-of-pocket expenditure, and fertility rate. These findings are consistent with the findings of the studies on health expenditure in the literature as summarized in the Introduction section.

The best first split GDP per capita divides the OECD countries into two groups (Node 1 and Node 2 in Fig.1) in terms of current health ex-

penditure as of 2015. Node 1 is a leaf node including the countries Chile (CHL), Colombia (COL), Czech Republic (CZE), Estonia (EST), Hungary (HUN), Latvia (LVA), Lithuania (LTU), Mexico (MEX), Poland (POL), Slovak Republic (SVK), and Turkey (TUR) with the decision rule GDPCD is equal to or less than US$ 17829.698. Three middle-income countries Colombia, Mexico, and Turkey are within this group. Other thirty-four OECD countries included in the analysis are high-income countries. Current health expenditures of countries grouped in Node 1 are given in Fig. 2 from the year 2000 to 2018, and their GDP per capita in Fig. 3. At the last branch level of the CHAID tree, among eight leaf nodes five of them contain a single country. Node 13 contains Italy (ITA) with the decision rule GDPCD is greater than US$ 17829.698, LIFEX is greater than 78.69 yr, DR is greater than 7 per 1,000 people, GDPCD is greater than US$ 25732.018, and FR is equal to or less than 1.4 births per woman. Fig. 4 presents the current health expenditure of Italy. In total CHAID decision tree classified thirty-seven OECD countries into eleven groups. Among these eleven leaf nodes, six of them (Node 3 and Nodes 9-13) contain a single country.

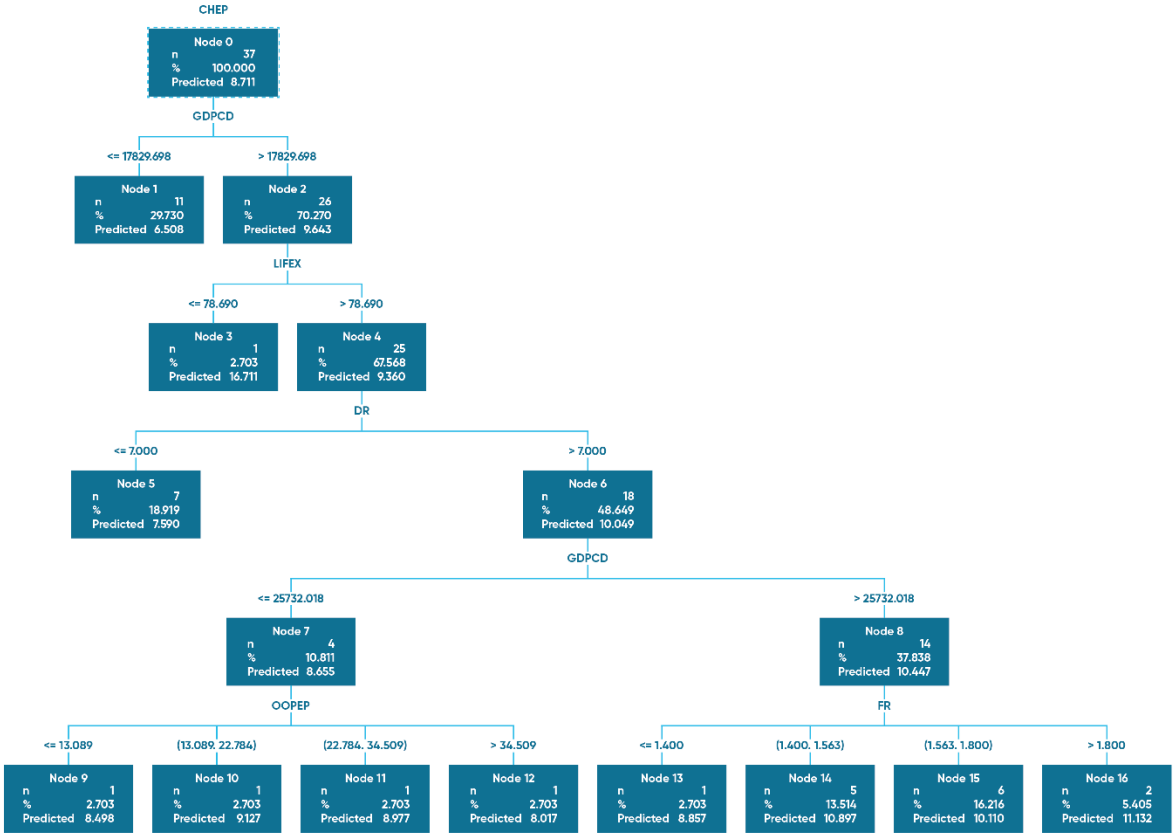

Fig. 1: CHAID decision tree for current health expenditure (% GDP)

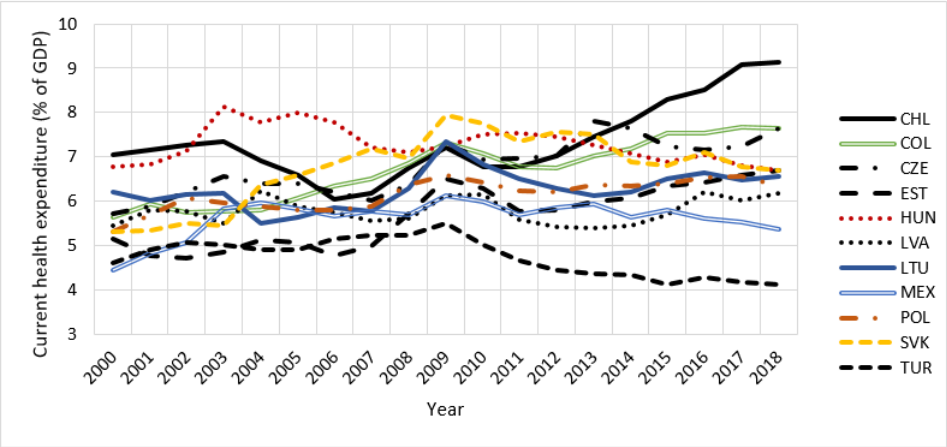

Fig. 2: Current health expenditures of countries included in Node 1

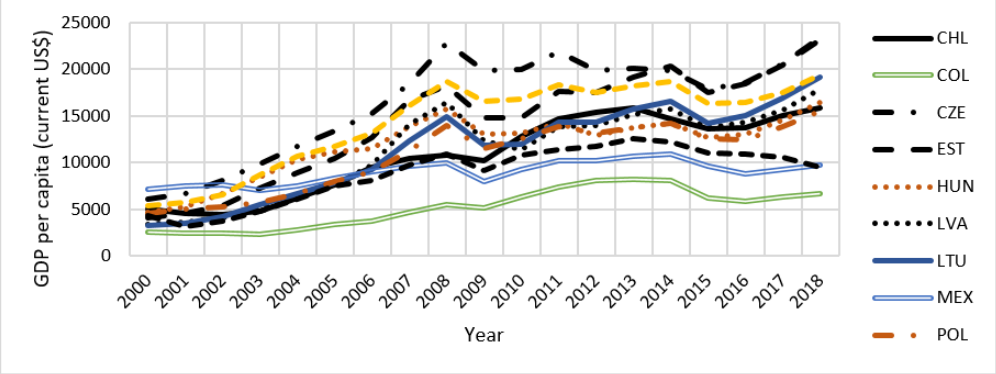

Fig. 3: GDP per capita of countries included in Node 1

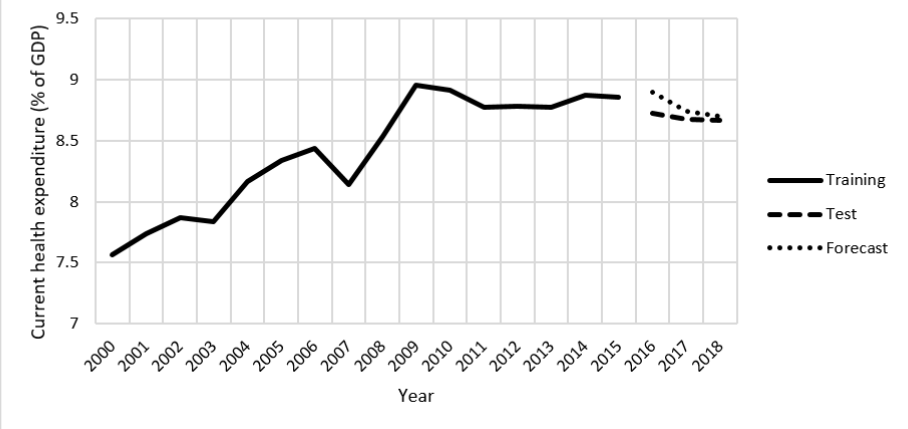

Fig. 4: Current health expenditure of Italy

The correlation coefficient (r) between predicted values and actual values of health expenditure of countries is 0.93, which is high and an indication of good predictive performance. In addition, to evaluate the success of the CHAID decision tree in identifying significant variables affecting health expenditure, the best subset regression is applied using these variables as explanatory variables. For

each country, the best regression model is selected based on the following criteria: the highest adjusted coefficient of determination (R-sq(adj)), the Mallows Cp value that is less than "the number of explanatory variables in the model + 1", and the lowest standard error of estimate (S).

The selected regression model for each country is fitted to the training set and forecasts were obtained. Forecasting errors are calculated using the test set and forecast accuracy is measured by MAPE (Table 2). Other than two countries, MAPE values are less than 10% while all MAPE values are less than 12% indicating very good forecast accuracy for the regression models. Therefore, the CHAID decision tree technique successfully identified the influential variables on current health expenditure. Regression models, selection criteria and forecast accuracy are given Table 2.

Table 2: Regression models, selection criteria and forecast accuracy

Country Code	*Regression model (CHEP =)*	*R-sq(adj) %*	*Mallows Cp*	*S*	*MAPE (%)*
AUS	-39.22 + 0.5876 LIFEX + 0.565 DR - 2.087 FR	91.94	2.5	0.13774	0.89
AUT	-20.85 + 1.95 FR + 0.462 DR + 0.2956 LIFEX	85.50	3.2	0.15516	2.11
BEL	-51.5 + 0.000043 GDPCD + 1.022 DR + 0.621 LIFEX	88.04	2.4	0.30588	4.94
CAN	-109.74 - 0.000085 GDPCD + 4.477 FR - 2.432 DR + 1.651 LIFEX	98.19	4.1	0.10872	6.22
CHL	-76.6 - 3.84 FR + 1.978 DR + 0.935 LIFEX	61.26	2.9	0.33078	5.95
COL	149.1 - 0.000242 GDPCD - 11.91 FR + 8.04 DR - 2.107 LIFEX	92.99	4.3	0.16604	4.61
CZE	-43.8 + 0.000015 GDPCD + 1.207 DR + 0.491 LIFEX	74.67	2.9	0.31646	7.64
DNK	-14.0 - 0.590 OOPEP + 2.69 FR + 0.346 LIFEX	84.78	2.0	0.30334	6.09
EST	-19.06 - 0.1673 OOPEP - 0.000088 GDPCD + 2.471 FR + 0.3456 LIFEX	87.36	5.0	0.22372	7.83
FIN	-46.5 - 0.290 OOPEP - 0.000044 GDPCD + 2.56 FR + 0.728 LIFEX	94.87	4.7	0.20426	0.72
FRA	-39.27 + 0.68 FR + 0.607 DR + 0.5360 LIFEX	91.25	2.2	0.20229	3.68
DEU	-15.32 - 3.59 FR + 0.758 DR + 0.288 LIFEX	70.61	2.4	0.25801	3.62
GRC	6.60 - 0.0793 OOPEP + 3.38 FR	70.53	1.6	0.31665	5.23
HUN	-1.75 - 0.1891 OOPEP - 4.66 FR + 0.586 DR + 0.1733 LIFEX	49.94	4.1	0.28868	4.12
ISL	52.7 - 0.370 OOPEP - 0.000030 GDPCD - 1.328 FR - 0.836 DR - 0.343 LIFEX	64.36	6.0	0.31989	1.21
IRL	-29.5 + 0.352 OOPEP - 0.000100 GDPCD + 7.76 FR - 2.00 DR + 0.460 LIFEX	91.42	6.0	0.50424	8.37
ISR	-6.62 + 0.0595 OOPEP + 0.814 FR + 0.1201 LIFEX	7.97	2.9	0.10723	3.52

Table 2: Continued…

ITA	-18.90 - 0.1221 OOPEP - 0.000036 GDPCD + 2.88 FR + 0.183 DR + 0.3130 LIFEX	92.91	6.0	0.12513	1.00
JPN	8.45 - 0.484 OOPEP + 0.843 DR	96.30	0.6	0.28245	4.53
KOR	-35.96 - 0.0630 OOPEP - 0.000052 GDPCD + 1.480 FR + 0.5413 LIFEX	98.98	4.6	0.09086	8.48
LVA	2.26 - 0.0540 OOPEP - 0.000082 GDPCD + 0.0898 LIFEX	23.08	2.4	0.23756	11.82
LTU	6.078 - 0.1109 OOPEP + 2.360 FR	65.54	0.7	0.26670	2.39
LUX	122.8 + 0.000022 GDPCD - 1.950 DR - 1.292 LIFEX	49.79	2.8	0.49446	1.98
MEX	-131.8 - 0.0758 OOPEP - 0.000184 GDPCD + 1.903 LIFEX	91.35	2.4	0.13392	9.30
NLD	-67.5 + 4.50 FR + 0.838 DR + 0.7766 LIFEX	88.57	2.1	0.30514	5.70
NZL	-87.0 - 0.000048 GDPCD + 1.394 FR + 1.176 LIFEX	90.49	2.1	0.25216	4.78
NOR	24.85 - 0.884 OOPEP - 0.000029 GDPCD	75.01	0.8	0.32249	3.54
POL	17.09 - 0.1595 OOPEP - 0.0904 LIFEX	84.02	0.6	0.13790	4.03
PRT	-4.55 - 0.1509 OOPEP + 0.000095 GDPCD + 1.67 FR + 0.170 LIFEX	73.34	4.0	0.22888	2.51
SVK	-0.05 + 0.0745 OOPEP + 0.000053 GDPCD + 3.46 FR	91.14	2.5	0.26339	9.83
SVN	3.93 - 0.301 OOPEP - 0.000033 GDPCD + 2.814 FR + 0.513 DR	73.84	4.2	0.19795	8.41
ESP	-33.79 - 0.3064 OOPEP - 0.000049 GDPCD + 0.6169 LIFEX	95.67	2.2	0.19426	5.83
SWE	-369.1 - 0.171 OOPEP - 6.22 FR + 4.49 DR + 4.290 LIFEX	92.13	4.0	0.36426	10.36
CHE	-76.6 - 3.84 FR + 1.978 DR + 0.935 LIFEX	61.26	2.9	0.33078	4.52
TUR	0.095 - 0.0424 OOPEP - 10.07 FR + 4.795 DR	87.89	3.9	0.13333	4.27
GBR	-46.90 - 0.0902 OOPEP - 0.000024 GDPCD + 1.50 FR + 0.6972 LIFEX	96.22	4.6	0.18564	1.86
USA	44.27 - 1.282 OOPEP - 0.000073 GDPCD - 1.077 DR	97.99	2.6	0.17761	2.73

Discussion

The main purpose of the health financing system was to create the necessary resources to cover the costs of health services. In recent years, most of the developing countries have focused on defining, estimating, and measuring health expenditures according to a valid method.

In this study, variables affecting health expenditures of OECD countries were investigated with the CHAID decision tree technique. According to the CHAID decision tree, GDP per capita, death rate, life expectancy at birth, out-of-pocket expenditure, and fertility rate are determined as the significant variables of health expenditures. The good performance of the regression model was

confirmed by the high correlation coefficient as shown in Table 2.

Health expenditures are covered by both the public and private sectors in many countries. The effects of health expenditures on health indicators have been discussed for a long time. Health expenditures and investments in health generally provide an improvement in health (29). Accurate prediction of health expenditures and determining influential variables provide proper planning of health investments.

The relationship between the income level of countries and health expenditures also has special importance. Countries with similar income levels may have different health expenditures in terms of quantity and quality. In a cross-country study (30), using data from the year 1994, the relationships between GDP per capita and health expenditure were investigated, and a strong direct relationship was found between per capita income and health expenditures, widely across countries. While leaving other variables constant, a country's income level has a very substantial association with its health expenditure rates. In our study, the GDPCD variable is included in the regression model and found as significant variable. Life expectancy at birth and GDP per capita are both statistically significant as previous studies have stated (2, 17, 24). Unlike previous studies, death rate, out-of-pocket expenditure, and fertility rate are all identified as significant variables as result of CHAID decision tree. The relationship between life expectany at birth and health expenditures is examined and identified with panel time series methods (2, 23); in our study, life expectancy at birth is identified as influential variable with CHAID technique.

The extent of out-of-pocket expenditures is much higher in developing countries. It is necessary to know and evaluate the factors affecting out-of-pocket health expenditures in which people have to spend a significant part of their current income to benefit from health services and deepen health inequality in low-income groups (31). A greater fertility rate results in increased health expenditures, particularly from the government, as well as increased financial strain on families and individuals, which slows down growth (32).

Conclusion

Based on the results of CHAID decision tree, GDP per capita, life expectancy at birth, death rate, out-of-pocket expenditure, and fertility rate are identified as the most influential variables on health expenditure.

The high value of the correlation coefficient between the predicted values and the actual values of health expenditure of countries is an indicator of good prediction performance. Moreover, the regression models built using the identified influential variables as explanatory variables give good forecast accuracy.

CHAID decision tree makes use of frequencies, not actual values, hence it does not require particular probability distributions for variables and is insensitive to outliers in the data sets. It provides a visual tool for decision rules and classification. The influential variables forming the decision rules can be used as inputs in other analyses.

The rising health spending forces the countries to strengthen their health systems and plan health spending budgets to adapt to that trend for financial sustainability. The CHAID decision tree technique is suggested as an effective tool in determining variables affecting health expenditure which in turn can be an important aid in health spending projections, health investments and planning. For future studies, epidemiological factors and income levels by country are examined and the decision tree and regression model can be applied accordingly.

Journalism Ethics considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

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Conflict of interest

The authors declare that they have no competing interest.

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