Identify factors that Have Effects on affect medical expenses

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Course: STAT350

Github Link:

https://github.com/Moring0213/STAT350FINALPROJECT

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Abstract

In this article, we will study to determine the factors affecting medical costs in the United States. For the data set under study, 1338 data and 7 variables are collected, which are the response variable expenses and the 6 explanatory variables we want to study. After research for scatter plot matrix and complete linear regression model analysis, we used the AIC and BIC model selection steps and selected two models. Then we build comparative tests on these two selected models. Through the use of ANOVA, the final model was determined and showed the influence of medical expenses on the following factors: 7 explanatory variables, 11 interaction variables, of which 7 influencing factors are more important, namely SEX, CHILDREN, AGE square, the interaction term BMI & smoking, BMI & living in SOUTHEAST, smoking & BMI over 30, smoking, and age square.

Keywords:
Medical expenses, AGE, SEX, Body Mass Index (BMI), CHILDREN, Smoking or not, Area of residence

Introduction

Dataset

The data set contains hypothetical medical expenses for patients in the United States. These data use demographic data from the US Census Bureau. It contains 1338 rows of data and the following columns: age, gender, BMI, children, smoker, region, charges, that is, the characteristics of the patient's characteristics and the total medical expenses calculated over the years.

Response Variables

Charges

Explanatory Variables

Variable definitions

The third to fifth variables are considered important explanatory variables and must be studied in the regression model.

1. AGE: Indicates the age of the main beneficiary (not including those over 64, because they are generally paid by the government) (integer)
2. SEX: The gender of the policy holder (categorical variable: 1 = male, 0 = female)
3. BMI: Body Mass Index (BMI),which provides a way to judge whether a person' s weight is overweight or underweight relative to height. The BMI index is equal to the weight (kg) divided by the height (m) square, a ideal BMI is in the range of 18.5~24.9(float)
4. CHILDREN: Indicates the number of children/dependents included in the insurance plan (integer)
5. SMOKER: A categorical variable with a value of yes or no, indicating whether the insured person smokes frequently (categorical variable: 1 = yes, 0 = no)
6. REGION: According to the beneficiary's residence in the United States, it is divided into 4 geographic regions (categorical variable: northeast, northwest, southeast, southwest), since there are multiple values, 3 variables are formed, namely REGION(NORTHWEST), REGION(SOUTHEAST), REGION(SOUTHWEST). (categorical variable: 1 = this region, 0 = not this region)

Variable statistics

Table 1.1: Statistical description of continuous variables

	AGE	BMI	CHILDREN	CHARGES
Min.	18	15.96	0	1122
1st Qu.	27	26.3	0	4740
Median	39	30.4	1	9382
Mean	39.21	30.66	1.095	13270
3rd Qu.	51	34.69	2	16640
Max.	64	53.13	5	63770

From Table 1.1, the average value of Age is 39.21 and the 3rd Qu. is 51; the average BMI is 30.66 and the 3rd Qu. is 34.69; the average CHILDREN is 1.095, and the 3rd Qu. is 2; the average of CHARGES is 13270, and the 3rd Qu. is 16640.

Table 1.2: Statistical description of categorical variables

Variables	Value	Number of people	Percentage of total
SEX	FEMALE	662	49%
	MALE	676	51%
SMOKER	NO	1064	80%
	YES	274	20%
REGION	NORTHEAST	324	24%
	NORTHWEST	325	24%
	SOUTHEAST	364	27%
	SOUTHWEST	325	24%

From Table 1.2, SEX and REGION are evenly distributed, and 20% of SMOKER is smoking.

Combining Table 1.1 and Table 1.2, since our predicted target is CHARGES, we choose the larger value of Age, BMI, and CHILDREN, and take the corresponding 3rd Qu., Age=51, BMI=34.69, CHILDREN=2, SEX=MALE, SMOKER=YES, REGION=NORTHWEST as the new observation sample (Data Point).

Analysis to do

1. Create features, build models, screen and compare the models, and determine a suitable linear regression model as the final model.
2. Analyze the goodness of fit of the final model.
3. Interpret the results of the final linear regression model to explain the variables and

explain the meaning of the variables.

Methods and models

In this paper, the multiple linear regression models were used to analyze the medical expenses data. Generally, when analyzing the data using the multiple linear regression models, the response variables would be considered as a linear function of the explanatory variables with an error variables term ε. If the data are appropriate to use the linear regression models, it should generally follow five assumptions:

1. The relationship between the response variable and the explanatory variable should be at least approximately linear.
2. The mean value of the error term ε is zero.
3. The variance of the error term should be constant.
4. The errors between different individuals are uncorrelated.
5. The error term should be normally distributed.

Therefore, check whether the relationship between the response variable and some explanatory variables is linear (first hypothesis). In the scatter plot matrix, outliers will be detected and whether the variables need to be transformed. The other party builds a more responsible model, including constructing nonlinear features, feature conversion, and adding variable interaction terms. Specifically include the following:

(1) Add a non-linear relationship

Age may not be constant for medical expenses: for older people, fees may be too expensive. Therefore, it is allowed to measure the influence of age by an age square. Variable name is age2.

(2) Conversion - convert a numeric variable into a binary indicator

Assume that the impact of a feature is not cumulative, but only when the feature reaches a given threshold. For example, for people in the normal weight range, the impact of BMI on medical expenses may be zero, but for obese people, it may be associated with higher expenses. Create a binary obesity indicator to establish this relationship, that is, if the BMI is greater than or equal to 30, then set to 1, otherwise set to 0.Variable name is bmi30.

(3) Model setting - adding the influence of interaction

Only consider the individual impact of each feature on the results. If certain features have a comprehensive impact on the corresponding variables, for example, smoking and obesity may have separate effects, the two joint marketing may get worse results than one alone. Therefore, construct bmi30*smoker.

The original features, plus structural features and interactive features, the completed model is as follows:

$$
\begin{aligned}
M1: E(\text{CHARGES}) = {} & \beta_0 + \beta_1 * AGE + \beta_2 * SEX + \beta_3 * BMI + \\
& \beta_4 * \text{CHILDREN} + \beta_5 * \text{SMOKER} + \\
& \beta_6 * \text{REGION(NORTHWEST)} + \\
& \beta_7 * \text{REGION(SOUTHEAST)} + \\
& \beta_8 * \text{REGION(SOUTHWEST)} + \\
& \beta_9 * (AGE * SEX) + \beta_{10} * (AGE * \text{SMOKER}) + \\
& \beta_{11} * (AGE * \text{REGION(NORTHWEST)}) + \\
& \beta_{12} * (AGE * \text{REGION(SOUTHEAST)}) + \\
& \beta_{13} * (AGE * \text{REGION(SOUTHWEST)}) + \\
& \beta_{14} * (BMI * SEX) + \beta_{15} * (BMI * \text{SMOKER}) + \\
& \beta_{16} * (BMI * \text{REGION(NORTHWEST)}) + \\
& \beta_{17} * (BMI * \text{REGION(SOUTHEAST)}) + \\
& \beta_{18} * (BMI * \text{REGION(SOUTHWEST)}) + \\
& \beta_{19} * (\text{CHILDREN} * SEX) + \beta_{20} * (\text{CHILDREN} * \text{SMOKER}) + \\
& \beta_{21} * (\text{CHILDREN} * \text{REGION(NORTHWEST)}) + \\
& \beta_{22} * (\text{CHILDREN} * \text{REGION(SOUTHEAST)}) + \\
& \beta_{23} * (\text{CHILDREN} * \text{REGION(SOUTHWEST)}) + \\
& \beta_{24} * BIM30 + \beta_{25} * AGE2 + \beta_{26} * (BIM30 * \text{SMOKER}) + \\
& \beta_{27} * (BIM30 * \text{SMOKER} * AGE2)
\end{aligned}
$$

where the variables SEX, SMOKE, REGION(NORTHWEST), REGION(SOUTHEAST) and REGION(SOUTHWEST) are categorical variables.

For the full model, the residuals plots, Q-Q plots and the histogram of the residuals will be studied to see whether the assumptions of the linear regression model are violated, and whether the variables need further transformation. Checking the summary table of the full model, 10 explanatory variables and 17 interaction between the explanatory variables are involved, but some of them may have no significant effect on the response variables CHARGES.

Consequently, in order to construct a good linear regression model with appropriate explanatory variables and interaction terms, Akaike’ s Information Criterion (AIC) and Bayesian’ s Information Criterion (BIC) model selection methods are used. As the data description emphasized that the five explanatory variables were important explanatory variables, all of the linear models should have them.

Therefore, in the model selection step, we would set the two base models, one was the full model and the other one was the following one with the least number of explanatory variables:

$$M0: E(\text{CHARGES}) = \beta_0 + \beta_1 * BMI + \beta_2 * \text{CHILDREN} + \beta_3 * \text{SMOKER}$$

where the variable SMOKE is categorical variable.

Then use stepwise regression to screen the model, using forward, backward and both methods, respectively, using AIC and BIC as standards to measure the effect of the model,

so a total of 6 models are obtained, and the models M_{AIC} and M_{BIC} with the smallest corresponding indicators are selected:

$$\begin{aligned} M_{AIC} : E(\text{CHARGES}) = {} & \beta_0 + \beta_1 * AGE + \beta_2 * SEX + \beta_3 * BMI + \\ & \beta_4 * \text{CHILDREN} + \beta_5 * \text{SMOKER} + \\ & \beta_6 * \text{REGION(NORTHWEST)} + \\ & \beta_7 * \text{REGION(SOUTHEAST)} + \\ & \beta_8 * \text{REGION(SOUTHWEST)} + \beta_9 * \text{BMI30} + \\ & \beta_{10} * \text{AGE2} + \beta_{11} * (AGE * \text{SMOKER}) + \\ & \beta_{12} * \text{BMI} * \text{SMOKER} + \\ & \beta_{13} * \text{BMI} * \text{REGION(NORTHWEST)} + \\ & \beta_{14} * \text{BMI} * \text{REGION(SOUTHEAST)} + \\ & \beta_{15} * \text{BMI} * \text{REGION(SOUTHWEST)} + \\ & \beta_{16} * \text{CHILDREN} * \text{SMOKER} + \\ & \beta_{17} * \text{SMOKER} * \text{BMI30} + \beta_{18} * \text{SMOKER} * \text{AGE2} \end{aligned}$$

where the variables SEX, SMOKE, REGION(NORTHWEST), REGION(SOUTHEAST) and REGION(SOUTHWEST) are categorical variables.

$$\begin{aligned} M_{BIC} : E(\text{CHARGES}) = {} & \beta_0 + \beta_1 * BMI + \beta_2 * \text{CHILDREN} + \\ & \beta_3 * \text{SMOKER} + \beta_4 * \text{BMI30} + \beta_5 * \text{AGE2} + \\ & \beta_6 * \text{BMI} * \text{SMOKER} + \beta_7 * \text{SMOKER} * \text{BMI30} \end{aligned}$$

where the variables SMOKE is categorical variable.

The t test and ANOVA test were used to select the final model in the above two models. Finally, the model M_{AIC} was chosen, and its residuals plot, Q-Q plot and the histogram for the distribution of the residuals were constructed so as to check whether this M_{AIC} model satisfied the five assumption of the multiple linear regression model.

Results

Scatterplots Matrix Study

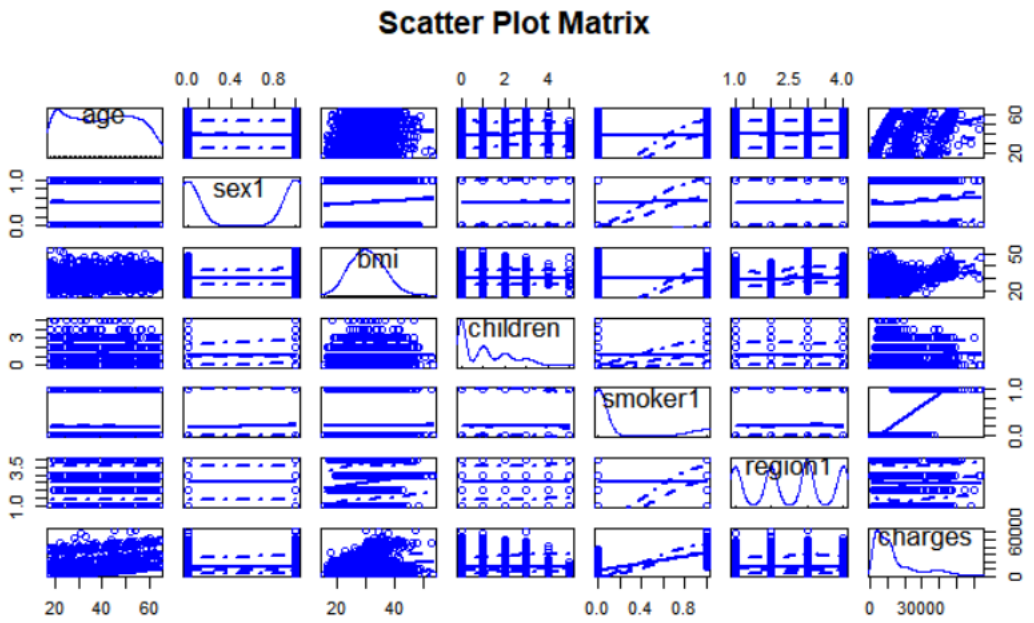


Figure 1: Scatterplots Matrix of the Response Variables and Explanatory Variables

Figure 1 is a scatter plot matrix of response variables. From the scatter plot, we observe that the explanatory variable AGE, BMI may be linearly related to the response variable CHARGES, but there seems to be no obvious relationship between the other variables (SEX, CHILDREN, SMOKE, and REGION) and the response variable.

From the CHARGES distribution chart, the data is not normally distributed, so other transformations such as logarithmic transformation, square transformation, etc. have been tried, but they have not been converted to normal distribution, so the original value is used for modeling, which may cause error terms Non-normal distribution.

Analysis on the full model

After constructing the full model with 10 explanatory variables (5 numerical variables and 5 categorical variables) and 17 interactions, we got the following summary table:

Table 2: Summary of full model M1					
Estimated σ	4378		Significant Predictors	Estimated Value	P-value
R^2	0.8722		CHILDREN	938.4134	0.000092^{***}

F-statistic	307.7		AGE2	4.617	1.08E-07***
F-stat P-value	< 2.2e-16***		BMI:SMOKER	518.313	2.15E-10***
			BMI:REGION(SOUTHEAST)	-141.3959	0.0109*
			SMOKER:BMI30	14038.5133	< 2e-16***
			SMOKER:AGE2	-3.7901	0.0364*

According to the R2 value, the full model could only explain 87.22% of the variability of the data. However, in all the 27 explanatory variables and interaction, the six terms, CHILDREN,AGE2,BMI:SMOKER,BMI:REGION(SOUTHEAST),SMOKER:BMI30,and SMOKER:AGE2 are significant with p-value<5%. Therefore, the model did follow the first assumption of the linear regression model.

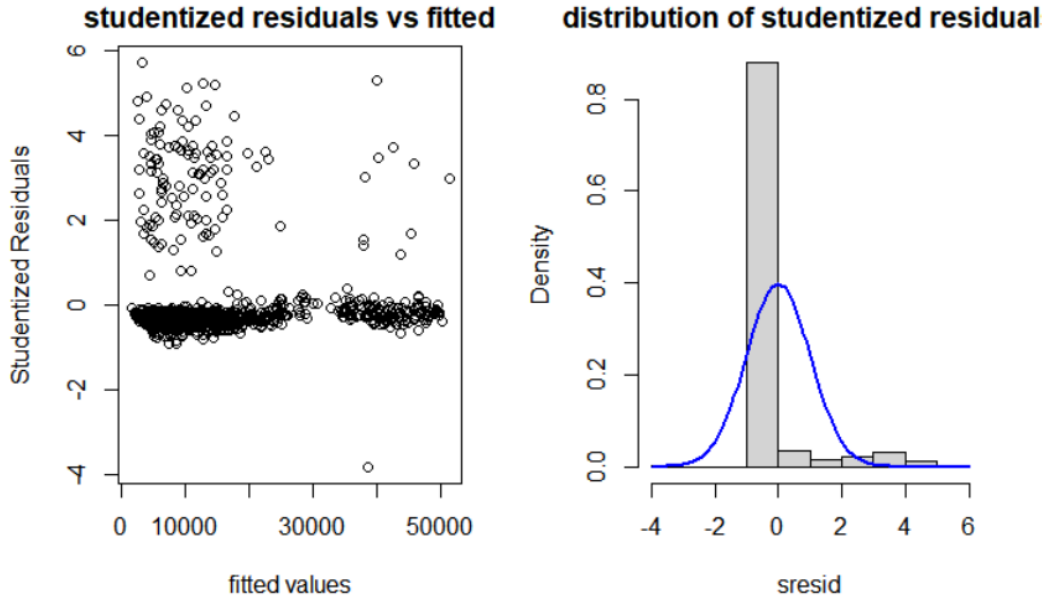


Figure 2: Studentized Residuals Plot (Studentized Residuals VS Fitted Values) and Histogram of residuals distribution

In addition, use studentized residual plots and residual distribution histograms to test the remaining four hypotheses. For the studentized residual plot in Figure 2 (the studentized residual VS the fitted value), the residuals are independent of each other. Most of them are randomly located on both sides of the y = 0 line, and the mean value of the difference = 0, but some of them are distributed away from each other. The far position of y=0 indicates that the variance is not necessarily constant. It follows the second and fourth assumptions of the multilinear model, but the third is not satisfied. In addition, in the histogram of residuals, the data does not appear to be normally distributed and does not follow the fifth hypothesis. Therefore, the complete model satisfies 3 assumptions of the linear regression model, and 2 of them are not satisfied. Since the predicted target charges also do not meet the normal distribution, the error term does not respect the normal distribution. Through the logarithmic sum of the target various transformations such as squaring still did not solve the problem, but from the

perspective of R^2, the model explained 87.22% of the information, and the regression model made some strong assumptions about the data. These strong assumptions are not so important for numerical prediction, because the value of the model lies in whether it really captures the basic process-since the model explains 87.22% of the information, we believe that the model has a high accuracy rate, so no further transformation is required.

To check the outliners, the scale-location plot and the residuals VS leverage plots in figure 3 were applied. In the scale-location plot, three outliners are observed. However, the Cook's distance for all the data points seemed small, which meant the outliners might not have significant effect on the model; therefore, we decided not to remove them.

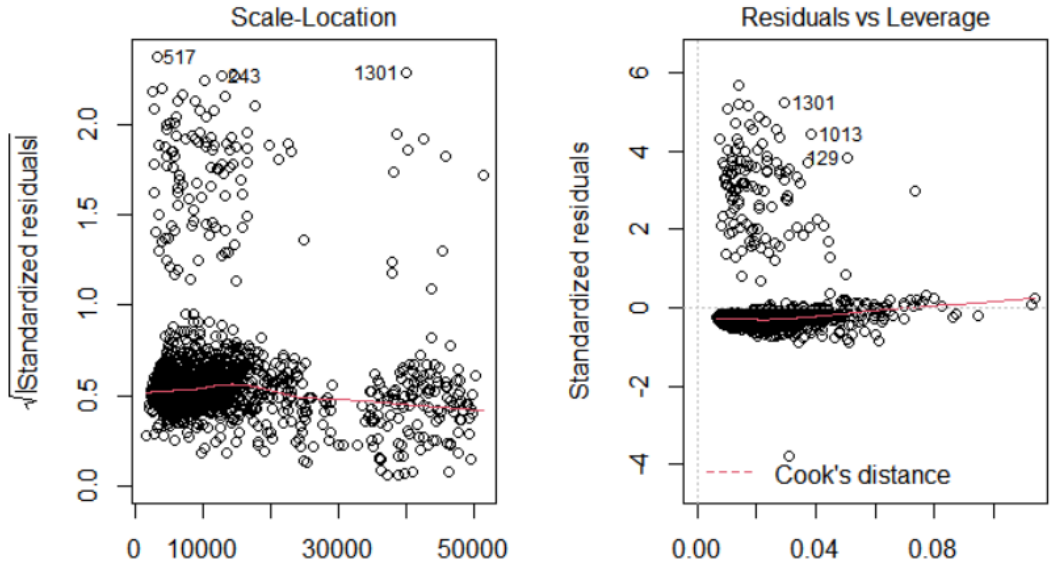


Figure 3: Scale-location plot and residuals VS leverage plot for full model M1

Model Selection

The AIC and BIC model selection steps were used to find the final model with appropriate variables. Finally, for AIC, the final selected model was M_{AIC}:

$$M_{AIC}: E(\text{CHARGES}) = \beta_0 + \beta_1 * AGE + \beta_2 * SEX + \beta_3 * BMI + \beta_4 * \text{CHILDREN} + \beta_5 * \text{SMOKER} + \beta_6 * \text{REGION(NORTHWEST)} + \beta_7 * \text{REGION(SOUTHEAST)} + \beta_8 * \text{REGION(SOUTHWEST)} + \beta_9 * \text{BMI30} + \beta_{10} * \text{AGE2} + \beta_{11} * (AGE * \text{SMOKER}) + \beta_{12} * \text{BMI} * \text{SMOKER} + \beta_{13} * \text{BMI} * \text{REGION(NORTHWEST)} + \beta_{14} * \text{BMI} * \text{REGION(SOUTHEAST)} + \beta_{15} * \text{BMI} * \text{REGION(SOUTHWEST)} + \beta_{16} * \text{CHILDREN} * \text{SMOKER} + \beta_{17} * \text{SMOKER} * \text{BMI30} + \beta_{18} * \text{SMOKER} * \text{AGE2}$$

where the variables *SEX*, SMOKE, REGION(NORTHWEST), REGION(SOUTHEAST) and REGION(SOUTHWEST) are categorical variables.

The summary table for the M_{AIC} is:

Table 3: Summary of model M_{AIC}

Estimated σ	4374		Significant Predictors	Estimated Value	P-value
R^2	0.8713		SEX	-504.7322	0.0365**
F-statistic	496.1		CHILDREN	773.129	3.86E-11***
F-stat P-value	< 2.2e-16***		AGE2	4.4349	1.31E-07***
			BMI:SMOKER	504.6852	4.88E-10***
			BMI:REGION(SOUTHEAST)	-129.0373	0.0183*
			SMOKER:BMI30	14853.6719	< 2e-16***
			SMOKER:AGE2	-3.4516	0.0496*

On the other hand, for BIC, the final selected model was M_{BIC}:

$$M_{BIC}: E(\text{CHARGES}) = \beta_0 + \beta_1 * BMI + \beta_2 * \text{CHILDREN} + \beta_3 * \text{SMOKER} + \beta_4 * \text{BMI30} + \beta_5 * \text{AGE2} + \beta_6 * \text{BMI} * \text{SMOKER} + \beta_7 * \text{SMOKER} * \text{BMI30}$$

where the variables SMOKE is categorical variable.

The summary table for the M_{BIC} is:

Table 4: Summary of model M_{BIC}					
Estimated σ	4409		Significant Predictors	Estimated Value	P-value
R^2	0.8682		CHILDREN	656.4832	7.57E-11***
F-statistic	1251		AGE2	3.349	< 2e-16***
F-stat P-value	< 2.2e-16***		BMI:SMOKER	489.4235	1.56E-09***
			SMOKER:BMI30	14770.1305	< 2e-16***

The difference between M_{AIC} and M_{BIC} was that the M_{AIC} had more terms than the M_{BIC} ; Therefore, the ANOVA was applied to test whether the M_{AIC} and M_{BIC} were significant different . The following table is the ANOVA table:

Table 5: ANOVA table for M_{BIC} VS M_{AIC}

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
M_{BIC}	1330	25850000000				
M_{AIC}	1319	25232000000	11	617882577	2.9363	0.00076***

The null hypothesis of the F test in the ANOVA table was that the model M_{AIC} with three more interaction terms was not significantly better than the model M_{BIC}, but the p-value was less than 1%; therefore, we had significant evidence to reject the null hypothesis, which meant the model M_{AIC} was significantly better than the M_{BIC}.

Two models are used to predict the new sample (Age=51, BMI=34.69, CHILDREN=2, SEX=MALE, SMOKER=YES, REGION=NORTHWEST) and the results are as follows:

Table 6: Forecast and 95% forecast interval table for M_{BIC} VS M_{AIC}

	fit	lwr	upr
M_{BIC}	44656.14	35973.15	53339.12
M_{AIC}	44831.02	36174.13	53487.9

Since the values of the new samples are relatively large, the result predicted by M_{BIC} is 44656.14, and the result predicted by M_{AIC} is 44831.02, both of which are greater than the 3rd Qu. of CHARGES, indicating that the selected new observation point corresponds to a higher cost, and M_{AIC} is higher than M_{BIC} 174.88.

Final model analysis

Therefore, the final model chosen is M_{AIC} . The R2 value indicates that M_{AIC} can explain 87.16% of the variability, and the p value of some items in M_{AIC} is much less than 1%. Although the model does not meet the five assumptions of linear regression, these strong assumptions are not so important for numerical prediction, because the value of the model lies in whether it really grasps the basic process-we care about the accuracy of the model prediction. So it is still concluded that M_{AIC} is a good final model.

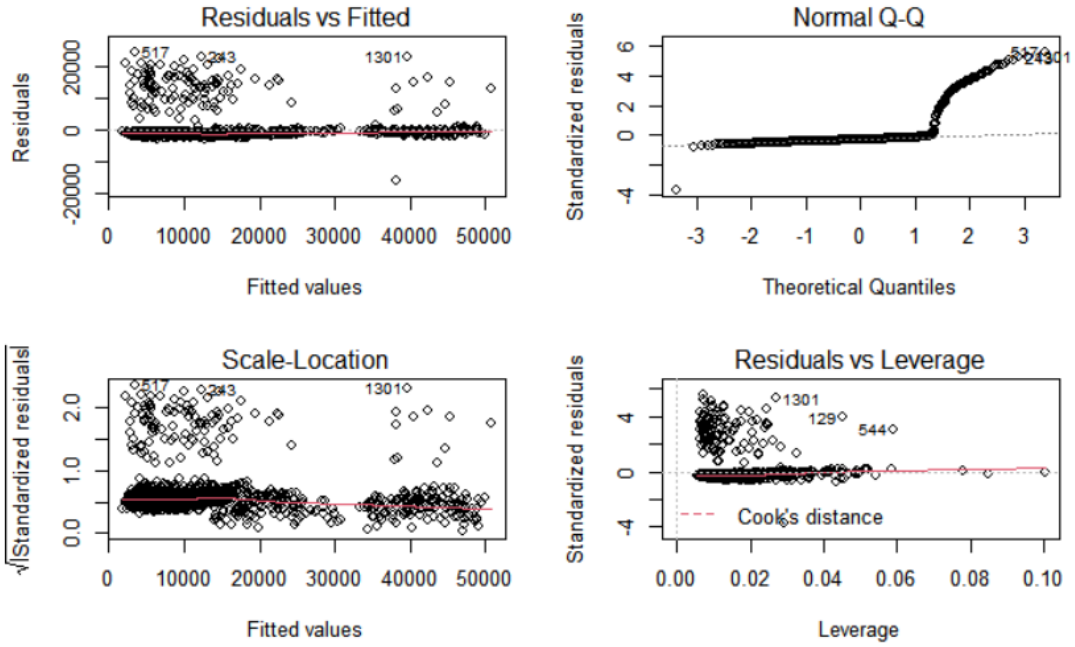


Figure 4.Linear regression model assumption diagnosis plot for M_{AIC}

Conclusion and discussion

According to the final model M_{AIC}, we can conclude that the charges is linear related to:
1. Age of beneficiary (AGE)
2. The gender of the policy holder (SEX)
3. Body mass index BMI (BMI)
4. Number of children/dependents included in the insurance plan (CHILDREN)
5. Does the insured smoke regularly (SMOKER)
6. Whether the beneficiary lives in the Northwest (REGION(NORTHWEST))
7. Whether the beneficiary lives in the Southeast (REGION(SOUTHEAST))
8. Whether the beneficiary lives in the Southwest (REGION(SOUTHWEST))
9. Does the body mass index BMI exceed 30 (BMI30)
10. The square of the beneficiary's age (AGE2)
11. The interaction between the age of the beneficiary and the number of insured people who smoke regularly (AGE:SMOKER)
12. The interaction between BMI and the number of insured people who smoke regularly (BMI: SMOKER)
13. The interaction between the body mass index BMI and whether the beneficiary lives in the northwest (BMI: REGION (NORTHWEST))
14. The interaction between the body mass index BMI and whether the beneficiary lives in the Southeast (BMI: REGION (SOUTHEAST))
15. The interaction between the body mass index BMI and whether the beneficiary lives in the southwest (BMI: REGION (SOUTHWEST))
16. The interaction between the number of children/dependents included in the insurance plan and whether the number of insured people smoke regularly (CHILDREN: SMOKER)
17. The interaction between whether the insured person smokes frequently and whether the body mass index BMI exceeds 30 (SMOKER: BMI30)
18. Does the number of insured smoke regularly and the square of the beneficiary's age (SMOKER:AGE2)

According to the results of the t-test in the summary table, the seven important variables detected in the above eighteen interpretations are SEX, CHILDREN, AGE2, the interaction term BMI: SMOKER, BMI: REGION (SOUTHEAST), SMOKER: BMI30, SMOKER: AGE2 . For seven important variables, the estimated coefficients are

Table 7: Estimated coefficients of significant explanatory variables in M_{AIC}	
SEX	-504.7322
CHILDREN	773.1290
AGE2	4.4349
BMI:SMOKER	504.6852
BMI:REGION(SOUTHEAST)	-129.0373
SMOKER:BMI30	14853.6719

SMOKER:AGE2	-3.4516

Based on the table 7, we made the following conclusion statement:

1. If the policy holder is male, the point estimation of charges will be 504.7322 lower than female, with other variables remaining constant.
2. The more children/dependents included in the insurance plan, the higher the cost, and the premium for one more child increases by 773.1290, while other variables remain unchanged.
3. The higher the square of the beneficiary’ s age, the higher the premium. The square of the beneficiary’ s age increases by 1 year and the cost increases by 4.4349, while other variables remain the same.
4. The BMI of smokers gains 1 unit, which is 504.6852 higher than the cost of non-smokers, while other variables remain unchanged.
5. The BMI of people living in SOUTHEAST increased by 1 unit, which is 129.0373 less than the cost of people living in other places, while other variables remain unchanged
6. People who smoke and have a BMI of more than 30 cost 14853.6719 more than others, while other variables remain the same.
7. The square of the age of the smoker increases by 1 unit, which is a decrease of 3.4516 compared to the cost of other people, while other variables remain unchanged.

Therefore, we know that the cost is related to the gender of the holder, the number of children/dependents, age, smoking, and BMI. Men need less expenses than women. The more children there are, the more expense is needed. Age is not linearly related to the cost. The older the age, the more the cost is. The cost of smokers is more than that of non-smokers, and the cost of smoking and overweight people is more than the cost of others.

Therefore we recommend:

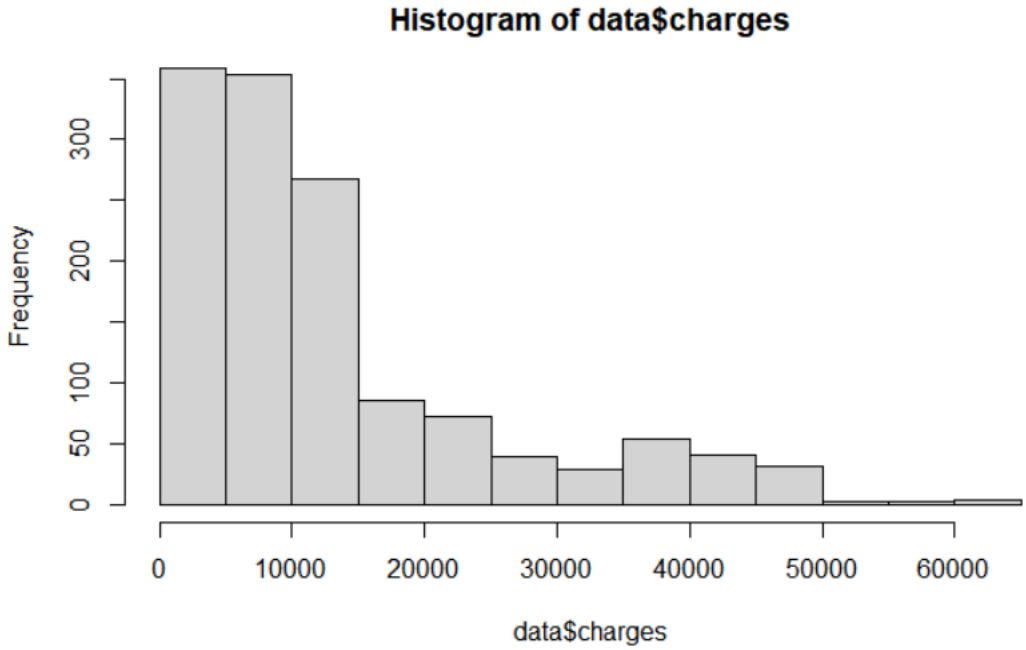
1. Appropriate weight control can reduce corresponding expenses;
2. Reducing smoking can also reduce costs;
3. For people who smoke and are overweight, more control is needed.

Reference

1.Machine learning and R language (2nd edition of the original book)[United States] Brett Lantz (Brett Lantz)
2.Introduction to Linear Regression Analysis (5th edition of the original book) [America] Douglas C. Montgomery, [America] Elizabeth A. Parker, [America] G. Jeffrey Vaining

Appendix

Distribution Histogram of charges:



Summary of Full Model:

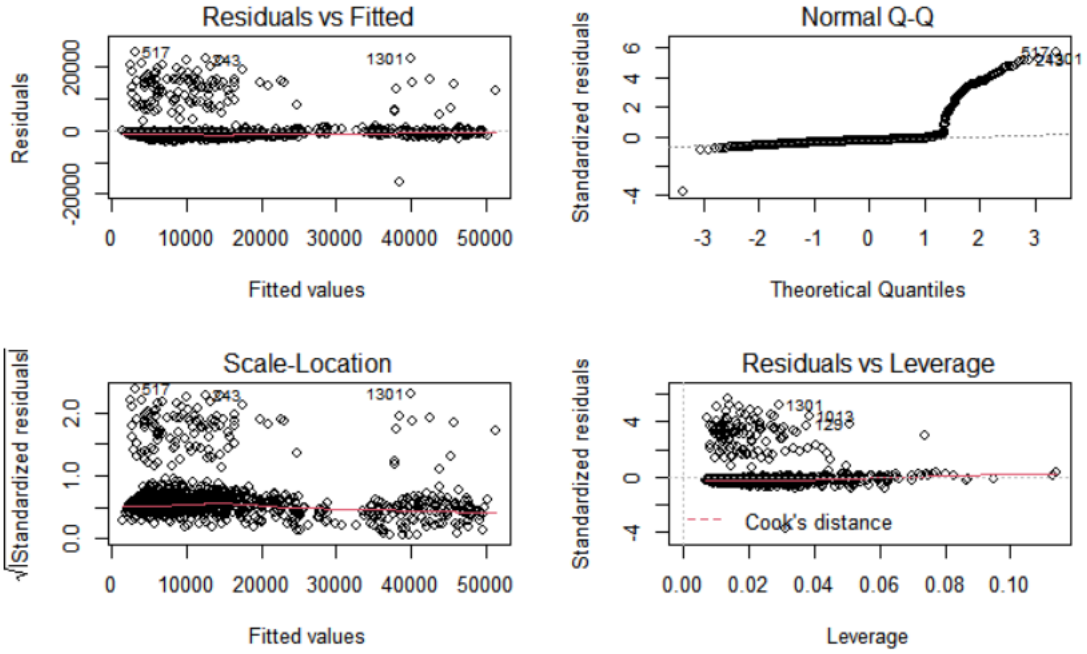
```
> summary(full_model)

Call:
lm(formula = charges ~ age + factor(sex) + bmi + children + factor(smoker) +
    factor(region) + age * factor(sex) + age * factor(smoker) +
    age * factor(region) + bmi * factor(sex) + bmi * factor(smoker) +
    bmi * factor(region) + children * factor(sex) + children *
    factor(smoker) + children * factor(region) + bmi30 + age2 +
    bmi30 * factor(smoker) + bmi30 * factor(smoker) * age2, data = data)

Residuals:
      Min        1Q    Median        3Q       Max
-16306.0  -1541.2  -1127.5   -788.3  24633.3

Coefficients:
                                Estimate Std. Error t value Pr(>|t|)
(Intercept)                   2099.7179  2034.4476   1.032   0.3022
age                           -119.8022    69.5935  -1.721   0.0854 .
factor(sex)male               -655.7014  1370.7482  -0.478   0.6325
bmi                             98.7780    55.7135   1.773   0.0765 .
children                       938.4134   239.2032   3.923 9.20e-05 ***
factor(smoker)yes            -3583.6372  3272.1619  -1.095   0.2736
factor(region)northwest        207.6148  2027.6963   0.102   0.9185
```

factor(region)southeast	2020.2367	1935.7204	1.044	0.2968	
factor(region)southwest	678.4660	1949.5983	0.348	0.7279	
bmi30	178.9560	622.9592	0.287	0.7740	
age2	4.6170	0.8642	5.343	1.08e-07	***
age:factor(sex)male	6.9244	17.3629	0.399	0.6901	
age:factor(smoker)yes	276.5174	141.8573	1.949	0.0515	.
age:factor(region)northwest	9.7962	24.7905	0.395	0.6928	
age:factor(region)southeast	44.6033	24.4673	1.823	0.0685	.
age:factor(region)southwest	32.3350	25.1526	1.286	0.1988	
factor(sex)male:bmi	-1.7713	40.2489	-0.044	0.9649	
bmi:factor(smoker)yes	518.3130	80.9783	6.401	2.15e-10	***
bmi:factor(region)northwest	-38.6155	63.6535	-0.607	0.5442	
bmi:factor(region)southeast	-141.3959	55.4383	-2.551	0.0109	*
bmi:factor(region)southwest	-94.6688	60.7423	-1.559	0.1193	
factor(sex)male:children	-64.8700	201.3796	-0.322	0.7474	
children:factor(smoker)yes	-467.7699	268.2450	-1.744	0.0814	.
children:factor(region)northwest	135.5779	293.2887	0.462	0.6440	
children:factor(region)southeast	-271.0908	284.2743	-0.954	0.3405	
children:factor(region)southwest	-356.9976	279.6649	-1.277	0.2020	
factor(smoker)yes:bmi30	14038.5133	1370.9914	10.240	< 2e-16	***
bmi30:age2	-0.1715	0.2474	-0.693	0.4885	
factor(smoker)yes:age2	-3.7901	1.8099	-2.094	0.0364	*
factor(smoker)yes:bmi30:age2	0.3896	0.5432	0.717	0.4734	

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 4378 on 1308 degrees of freedom
Multiple R-squared: 0.8722, Adjusted R-squared: 0.8693
F-statistic: 307.7 on 29 and 1308 DF, p-value: < 2.2e-16

Diagnosis Plots for full model:



Model Selection Step:

Table 2: Final selected model from three selecting direction (forward, backward and both) and two information criteria (AIC and BIC)Information

information criteria	Selection Direction	Final Selected Model	AIC/BIC value for final model
AIC	Forward	CHARGES ~ AGE + SEX + BMI + CHILDREN + SMOKER + REGION(NORTHWEST) + REGION(SOUTHEAST) + REGION(SOUTHWEST) + BMI30 + AGE2 + AGE:SEX + AGE:SMOKER + AGE:REGION(NORTHWEST) + AGE:REGION(SOUTHEAST) + AGE:REGION(SOUTHWEST) + SEX:BMI + BMI:SMOKER + BMI:REGION(NORTHWEST) + BMI:REGION(SOUTHEAST) + BMI:REGION(SOUTHWEST) + SEX:CHILDREN + CHILDREN:SMOKER + CHILDREN:REGION(NORTHWEST) + CHILDREN:REGION(SOUTHEAST) + CHILDREN:REGION(SOUTHWEST) + SMOKER:BMI30 + BMI30:AGE2 + SMOKER:AGE2 + SMOKER:BMI30:AGE2	26264.98

AIC	Backward	CHARGES ~ AGE + SEX + BMI + CHILDREN + SMOKER + REGION(NORTHWEST) + REGION(SOUTHEAST) + REGION(SOUTHWEST) + BMI30 + AGE2 + AGE:SMOKER + BMI:SMOKER + BMI:REGION(NORTHWEST) + BMI:REGION(SOUTHEAST) + BMI:REGION(SOUTHWEST) + CHILDREN:SMOKER + SMOKER:BMI30 + SMOKER:AGE2	26251.86
AIC	Both	CHARGES ~ AGE + SEX + BMI + CHILDREN + SMOKER + REGION(NORTHWEST) + REGION(SOUTHEAST) + REGION(SOUTHWEST) + BMI30 + AGE2 + AGE:SMOKER + BMI:SMOKER + BMI:REGION(NORTHWEST) + BMI:REGION(SOUTHEAST) + BMI:REGION(SOUTHWEST) + CHILDREN:SMOKER + SMOKER:BMI30 + SMOKER:AGE2	26251.86
BIC	Forward	CHARGES ~ AGE + SEX + BMI + CHILDREN + SMOKER + REGION(NORTHWEST) + REGION(SOUTHEAST) + REGION(SOUTHWEST) + BMI30 + AGE2 + AGE:SEX + AGE:SMOKER + AGE:REGION(NORTHWEST) + AGE:REGION(SOUTHEAST) + AGE:REGION(SOUTHWEST) + SEX:BMI + BMI:SMOKER + BMI:REGION(NORTHWEST) + BMI:REGION(SOUTHEAST) + BMI:REGION(SOUTHWEST) + SEX:CHILDREN + CHILDREN:SMOKER + CHILDREN:REGION(NORTHWEST) + CHILDREN:REGION(SOUTHEAST) + CHILDREN:REGION(SOUTHWEST) + SMOKER:BMI30 + BMI30:AGE2 + SMOKER:AGE2 + SMOKER:BMI30:AGE2	26426.14
BIC	Backward	CHARGES ~ BMI + CHILDREN + SMOKER + BMI30 + AGE2 + BMI:SMOKER + SMOKER:BMI30	26309.02
BIC	Both	CHARGES ~ BMI + CHILDREN + SMOKER + BMI30 + AGE2 + BMI:SMOKER + SMOKER:BMI30	26309.02

Summary of M_{AIC} :

```
> summary(full_model_aic)
Call:
lm(formula = charges ~ age + factor(sex) + bmi + children + factor(smoker) +
    factor(region) + bmi30 + age2 + age:factor(smoker) + bmi:factor(smoker) +
    bmi:factor(region) + children:factor(smoker) + factor(smoker):bmi30 +
    factor(smoker):age2, data = data)

Residuals:
     Min       1Q   Median       3Q      Max
-16087.2  -1554.6  -1183.7   -793.3  24257.3
```

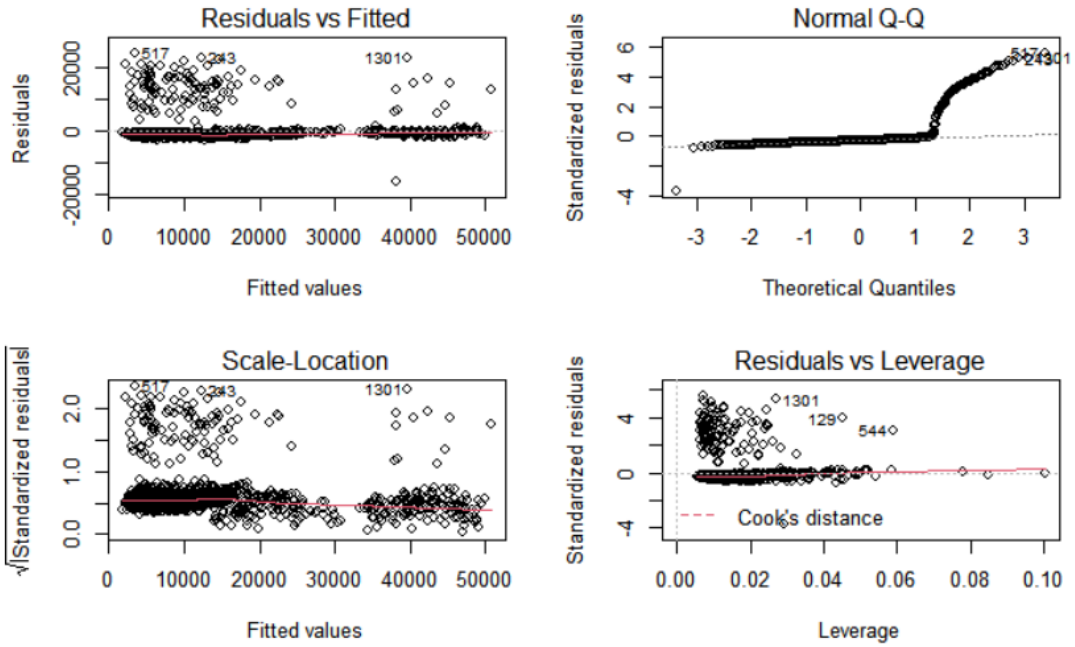
Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	1563.7263	1841.3542	0.849	0.3959	
age	-87.6725	66.9525	-1.309	0.1906	
factor(sex)male	-504.7322	241.1028	-2.093	0.0365	*
bmi	90.1593	52.4342	1.719	0.0858	.
children	773.1290	115.9852	6.666	3.86e-11	***
factor(smoker)yes	-3560.7550	3245.9191	-1.097	0.2728	
factor(region)northwest	429.0807	1869.2054	0.230	0.8185	
factor(region)southeast	3115.6063	1725.7928	1.805	0.0713	.
factor(region)southwest	1292.1316	1813.7951	0.712	0.4763	
bmi30	-128.5024	451.7184	-0.284	0.7761	
age2	4.4349	0.8357	5.307	1.31e-07	***
age:factor(smoker)yes	271.0136	141.1204	1.920	0.0550	.
bmi:factor(smoker)yes	504.6852	80.4905	6.270	4.88e-10	***
bmi:factor(region)northwest	-26.9653	62.9421	-0.428	0.6684	
bmi:factor(region)southeast	-129.0373	54.6011	-2.363	0.0183	*
bmi:factor(region)southwest	-85.4853	59.4985	-1.437	0.1510	
children:factor(smoker)yes	-487.7672	265.5281	-1.837	0.0664	.
factor(smoker)yes:bmi30	14853.6719	1002.9986	14.809	< 2e-16	***
factor(smoker)yes:age2	-3.4516	1.7563	-1.965	0.0496	*

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 4374 on 1319 degrees of freedom
Multiple R-squared: 0.8713, Adjusted R-squared: 0.8696
F-statistic: 496.1 on 18 and 1319 DF, p-value: < 2.2e-16

Diagnosis Plots for M_{AIC} :



Summary of M_{BIC} :

> summary(full_model_bic)

Call:

lm(formula = charges ~ bmi + children + factor(smoker) + bmi30 +
age2 + bmi:factor(smoker) + factor(smoker):bmi30, data = data)

Residuals:

Min	1Q	Median	3Q	Max
-16110.2	-1477.0	-1278.6	-838.7	23844.3

Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	1884.9675	979.6980	1.924	0.0546	.
bmi	-2.0314	37.1540	-0.055	0.9564	
children	656.4832	100.0385	6.562	7.57e-11	***
factor(smoker)yes	999.1526	2087.5968	0.479	0.6323	
bmi30	70.6508	448.6695	0.157	0.8749	
age2	3.3490	0.1079	31.047	< 2e-16	***
bmi:factor(smoker)yes	489.4235	80.4884	6.081	1.56e-09	***
factor(smoker)yes:bmi30	14770.1305	1007.9438	14.654	< 2e-16	***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 4409 on 1330 degrees of freedom
Multiple R-squared: 0.8682, Adjusted R-squared: 0.8675
F-statistic: 1251 on 7 and 1330 DF, p-value: < 2.2e-16

Diagnosis Plots for M_{BIC} :