Regression Analysis

Regression Analysis in Practice

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Emergency Department Healthcare Costs: Variable Selection

About This Lesson

Lasso Regression

```
predictors = as.matrix(dataAdult[, -c(1, 2, 3, 4, 5, 10, 13, 18)])

# Set up indicator (dummy) variables for State and Urbanicity
# Leave out one indicator (dummy) variable for each group

#AL= rep(0, length(State))
AR = rep(0, length(State))
LA = rep(0, length(State))
NC = rep(0, length(State))
#AL[as.numeric(State)==1] = 1
 AR[as.numeric(State)==2] = 1
 LA[as.numeric(State)==3] = 1
 NC[as.numeric(State)==4] = 1

#rural   = rep(0, length(Urbanicity))
suburban = rep(0, length(Urbanicity))
urban    = rep(0, length(Urbanicity))
#  rural[as.numeric(Urbanicity)==1] = 1
suburban[as.numeric(Urbanicity)==2] = 1
   urban[as.numeric(Urbanicity)==3] = 1

predictors = cbind(predictors, AR, LA, NC, suburban, urban)
```

Lasso Regression

```
## 10-fold CV to find the optimal lambda
lassomodel.cv = cv.glmnet(predictors, log(EDCost.pmpm), alpha=1, nfolds=10)

## Fit lasso model with 100 values for lambda
lassomodel = glmnet(predictors, log(EDCost.pmpm), alpha=1, nlambda=100)

## Plot coefficient paths
plot(lassomodel, xvar="lambda", label=TRUE, lwd=2)
abline(v=log(lassomodel.cv$lambda.min), col='black', lty=2, lwd=2)

## Extract coefficients at optimal lambda
coef(lassomodel, lassomodel.cv$lambda.min)
```

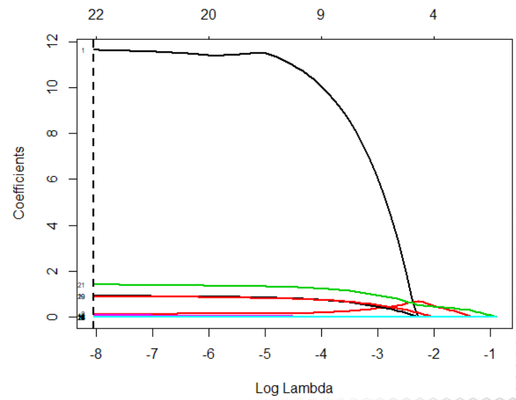
Lasso Regression

(Intercept)	2.277008e+00
HO	1.162649e+01
PO	1.389343e-01
WhitePop	3.767074e-03
BlackPop	4.246413e-03
HealthyPop	-1.042170e-03
ChronicPop	-5.704991e-03
Unemployment	3.421637e-04
Income	-2.307290e-07
Poverty	-2.383079e-04
Education	-1.451700e-03
Accessibility	-1.831102e-03
Availability	7.664592e-02
RankingsPCP	7.194696e-04
RankingsFood	5.782113e-03
RankingsHousing	-4.587208e-03
RankingsExercise	3.969711e-04
RankingsSocial	.
ProvDensity	5.923880e-02
AR	9.183680e-01
LA	9.027530e-01
NC	1.410464e+00
suburban	-7.302043e-05
urban	2.096038e-02

High-coefficient path corresponds to *HO* variable

RankingsSocial dummy variable is <u>not</u> selected

Other large-coefficient paths correspond to State dummy variables (*AR*, *LA*, *NC*)



Elastic Net Regression

10-fold CV to find the optimal lambda
enetmodel.cv = cv.glmnet(predictors, log(EDCost.pmpm), alpha=0.5, nfolds=10)

Fit lasso model with 100 values for lambda
enetmodel = glmnet(predictors, log(EDCost.pmpm), alpha=0.5, nlambda=100)

Plot coefficient paths
plot(enetmodel, xvar="lambda", label=TRUE, lwd=2)
abline(v=log(enetmodel.cv$lambda.min), col='black', lty=2, lwd=2)

Extract coefficients at optimal lambda
coef(enetmodel, s=enetmodel.cv$lambda.min)

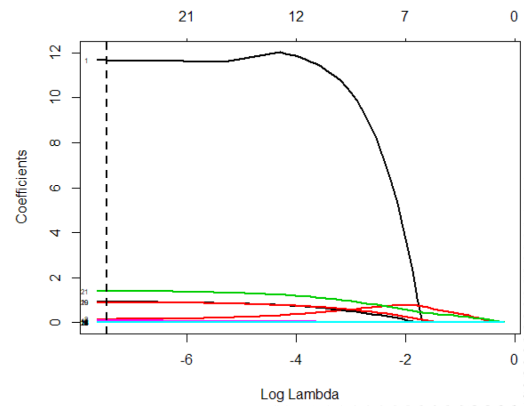
Elastic Net Regression

(Intercept)	2.288092e+00
HO	1.165709e+01
PO	1.478576e-01
WhitePop	3.688873e-03
BlackPop	4.184739e-03
HealthyPop	-1.170339e-03
ChronicPop	-5.767968e-03
Unemployment	3.568585e-04
Income	-2.361412e-07
Poverty	-2.646852e-04
Education	-1.451879e-03
Accessibility	-1.859399e-03
Availability	7.703073e-02
RankingsPCP	7.168545e-04
RankingsFood	5.944554e-03
RankingsHousing	-4.569033e-03
RankingsExercise	4.221634e-04
RankingsSocial	.
ProvDensity	5.941349e-02
AR	9.140417e-01
LA	8.996673e-01
NC	1.404530e+00
suburban	-3.213212e-04
urban	2.105330e-02

High-coefficient path corresponds to *HO* variable

RankingsSocial dummy variable is <u>not</u> selected

Other large-coefficient paths correspond to State dummy variables (*AR*, *LA*, *NC*)



Stepwise Regression

full = lm(log(EDCost.pmpm) ~ HealthyPop + ChronicPop + State + Urbanicity + HO + PO +
BlackPop + WhitePop + Unemployment + Income + Poverty+ Education +
Accessibility + Availability + ProvDensity +
RankingsPCP + RankingsFood + RankingsExercise + RankingsSocial)
minimum = lm(log(EDCost.pmpm) ~ HealthyPop + ChronicPop)
 # Forward Stepwise Regression
forward.model = step(minimum, scope=list(lower=minimum, upper=full), direction="forward")
summary(forward.model)
 # Backward Stepwise Regression
backward.model = step(full, scope=list(lower=minimum, upper=full), direction = "backward")
summary(backward.model)
 # Forward-Backward Stepwise Regression
both.min.model = step(minimum, scope=list(lower=minimum, upper=full), direction = "both")
summary(both.min.model)

Stepwise Regression

Observations

- Some variables were not selected by any method
  - *Unemployment*, *Income*, *Poverty*, *RankingExercise*
- *UrbanicitySuburban* was not statistically significant in any model
- Variables selected first by forward stepwise regression, in order
  - State dummy variables (*StateAR, StateLA, StateNC*)
  - Number of claims per-member-per-month *(HO, PO)*

Stepwise Regression Model

- Two models to consider
  - Forward stepwise regression selected *RankingsSocial*

summary(forward.model)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	2.397e+00	1.008e-01	23.789	< 2e-16 ***
HealthyPop	-2.143e-03	8.196e-04	-2.615	0.008945 **
ChronicPop	-7.301e-03	2.085e-03	-3.501	0.000467 ***
StateAR	1.011e+00	1.348e-02	75.041	< 2e-16 ***
StateLA	9.231e-01	1.228e-02	75.145	< 2e-16 ***
StateNC	1.482e+00	1.304e-02	113.630	< 2e-16 ***
HO	9.896e-04	9.043e-05	10.943	< 2e-16 ***
PO	-3.928e-05	4.952e-06	-7.933	2.61e-15 ***
Education	-1.635e-03	2.436e-04	-6.715	2.09e-11 ***
ProvDensity	6.105e-02	1.581e-02	3.861	0.000114 ***
RankingsPCP	7.457e-04	1.641e-04	4.543	5.67e-06 ***
Availability	1.006e-01	1.942e-02	5.180	2.30e-07 ***
Accessibility	-2.551e-03	7.118e-04	-3.584	0.000342 ***
RankingsFood	1.571e-02	4.241e-03	3.705	0.000214 ***
RankingsSocial	1.014e-03	1.351e-03	0.750	0.453169
UrbanicitySuburban	9.041e-03	1.384e-02	0.653	0.513725
UrbanicityUrban	2.708e-02	1.278e-02	2.118	0.034197 *
BlackPop	4.159e-03	5.871e-04	7.084	1.60e-12 ***
WhitePop	4.059e-03	5.833e-04	6.959	3.87e-12 ***

Residual standard error: 0.2357 on 5000 degrees of freedom
Multiple R-squared: 0.8437, Adjusted R-squared: 0.8431
F-statistic: 1499 on 18 and 5000 DF, p-value: < 2.2e-16

summary(backward.model)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	2.403e+00	1.005e-01	23.905	< 2e-16 ***
HealthyPop	-2.172e-03	8.187e-04	-2.653	0.008015 **
ChronicPop	-7.228e-03	2.083e-03	-3.470	0.000524 ***
StateAR	1.011e+00	1.344e-02	75.199	< 2e-16 ***
StateLA	9.209e-01	1.194e-02	77.157	< 2e-16 ***
StateNC	1.482e+00	1.303e-02	113.694	< 2e-16 ***
UrbanicitySuburban	9.280e-03	1.384e-02	0.671	0.502523
UrbanicityUrban	2.550e-02	1.261e-02	2.022	0.043193 *
HO	9.913e-04	9.040e-05	10.966	< 2e-16 ***
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Education	-1.642e-03	2.434e-04	-6.746	1.69e-11 ***
Accessibility	-2.538e-03	7.116e-04	-3.566	0.000366 ***
Availability	1.005e-01	1.941e-02	5.177	2.34e-07 ***
ProvDensity	6.172e-02	1.579e-02	3.910	9.36e-05 ***
RankingsPCP	7.736e-04	1.599e-04	4.838	1.35e-06 ***
RankingsFood	1.508e-02	4.158e-03	3.628	0.000288 ***

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Stepwise Regression Model

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Both models explain the same amount of variance (about 84%). Prefer the smaller model.

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UrbanicitySuburban is not statistically significant at $\alpha = 0.05$.

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Access to primary care (*Accessibility* and *Availability*) is statistically significantly associated to ED cost.

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Stepwise Regression Vs Full Models

Compare full model to selected model

reg.step = lm(log(EDCost.pmpm) ~ HealthyPop + ChronicPop + State + Urbanicity + HO
+ PO + BlackPop + WhitePop + Education + Accessibility + Availability
+ ProvDensity + RankingsPCP + RankingsFood)

anova(reg.step, full)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	5001	277.80				
2	4996	277.69	5	0.11778	0.4238	0.8324

- P-value large
  - Do not reject the null hypothesis (reduced model)
- The reduced model is plausibly as good in terms of explanatory power as the full model

Residual Analysis: Outliers & Normality

```
red.resid = residuals(reg.step)
red.cook = cooks.distance(reg.step)

## Check outliers
influencePlot(reg.step)
plot(red.cook,type="h",lwd=3,col="red", ylab = "Cook's Distance")

## Check normality
qqPlot(red.resid, ylab="Residuals", main = "")
qqline(red.resid, col="red", lwd=2)
hist(red.resid, xlab="Residuals", main = "", nclass=30, col="orange")
```

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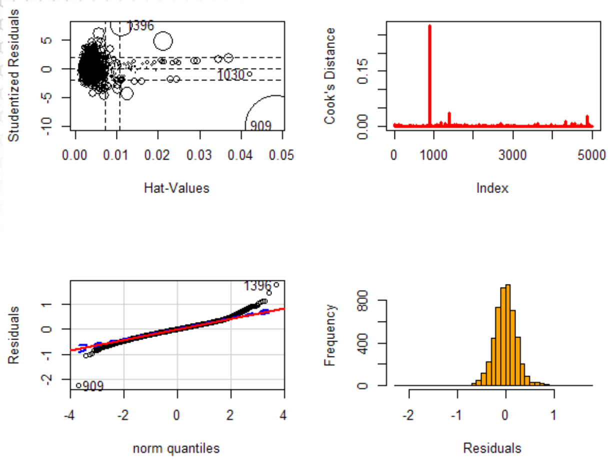
Residual Analysis: Outliers & Normality



Outliers

Observation 909 stands out

Normality

Symmetric but with heavy tails

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Removing Outlier

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StateAR	1.011e+00	1.344e-02	75.199	< 2e-16 ***
StateLA	9.209e-01	1.194e-02	77.157	< 2e-16 ***
StateNC	1.482e+00	1.303e-02	113.694	< 2e-16 ***
UrbanicitySuburban	9.280e-03	1.384e-02	0.671	0.502523
UrbanicityUrban	2.550e-02	1.261e-02	2.022	0.043193 *
HO	9.913e-04	9.040e-05	10.966	< 2e-16 ***
PO	-3.933e-05	4.951e-06	-7.943	2.42e-15 ***
BlackPop	4.269e-03	5.686e-04	7.507	7.10e-14 ***
WhitePop	4.180e-03	5.606e-04	7.456	1.04e-13 ***
Education	-1.642e-03	2.434e-04	-6.746	1.69e-11 ***
Accessibility	-2.538e-03	7.116e-04	-3.566	0.000366 ***
Availability	1.005e-01	1.941e-02	5.177	2.34e-07 ***
ProvDensity	6.172e-02	1.579e-02	3.910	9.36e-05 ***
RankingsPCP	7.736e-04	1.599e-04	4.838	1.35e-06 ***
RankingsFood	1.508e-02	4.158e-03	3.628	0.000288 ***

Residual standard error: 0.2357 on 5001 degrees of freedom
Multiple R-squared: 0.8437 Adjusted R-squared: 0.8432
F-statistic: 1588 on 17 and 5001 DF, p-value: < 2.2e-16

summary(backward.model.no.out)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	1.9356344	0.0991296	19.526	< 2e-16 ***
HealthyPop	0.0003798	0.0007824	0.485	0.627430
ChronicPop	-0.0010849	0.0020519	-0.529	0.597031
StateAR	0.9379139	0.0154403	60.745	< 2e-16 ***
StateLA	0.8989533	0.0117596	76.444	< 2e-16 ***
StateNC	1.4282364	0.0156224	91.422	< 2e-16 ***
UrbanicitySuburban	-0.0006647	0.0135555	-0.049	0.960895
UrbanicityUrban	0.0222961	0.0123314	1.808	0.070654 .
HO	11.5397384	0.7193214	16.043	< 2e-16 ***
PO	0.1338608	0.0403440	3.318	0.000913 ***
BlackPop	0.0050502	0.0005547	9.105	< 2e-16 ***
WhitePop	0.0044178	0.0005478	8.064	9.14e-16 ***
Education	-0.0017147	0.0002292	-7.480	8.72e-14 ***
Accessibility	-0.0018658	0.0006940	-2.688	0.007205 **
Availability	0.0755848	0.0189930	3.980	7.00e-05 ***
ProvDensity	0.0654339	0.0154862	4.225	2.43e-05 ***
RankingsPCP	0.0007560	0.0001564	4.835	1.37e-06 ***
RankingsFood	0.0162198	0.0040412	4.014	6.07e-05 ***

Residual standard error: 0.2301 on 5000 degrees of freedom
Multiple R-squared: 0.8504 Adjusted R-squared: 0.8499
F-statistic: 1672 on 17 and 5000 DF, p-value: < 2.2e-16

Model Interpretation: State Differences

Comparing 2011 ED Costs by Location (AL, AR, LA, and NC)

- Controlling for utilization, access, and socioeconomics
  - In AR versus AL
    - ED cost PMPM is exp(0.938) = $2.55 higher
    - ED cost per member per year is $30.65 higher
  - In LA versus AL
    - ED cost PMPM is exp(0.899) = $2.46 higher
    - ED cost per member per year is $29.49 higher
  - In NC versus AL
    - ED cost PMPM is exp(1.428) = $4.17 higher
    - ED cost per member per year is $50.04 higher

Overall Interpretation: Controlling for many potential factors contributing to ED costs, North Carolina pays significantly more while Alabama pays significantly less per member on emergency care than do Louisiana and Arkansas.

Model Interpretation: Utilization

Healthcare Utilization

- *PO*
  - Proxy of regular care utilization
  - Number of claims reimbursed for care in a physician's office
- *HO*
  - Proxy of inpatient care utilization
  - Number of claims reimbursed for hospital care

Interpretation

- An increase of 1 claim PMPM for regular care results in a 0.133 increase in log of ED cost PMPM, given all other predictors fixed
- An increase of 1 claim PMPM for inpatient care results in a 11.54 increase in log of ED cost PMPM, given all other predictors fixed

Model Interpretation: Access to Care

Access to primary care

- *Availability*
  - Proxy of wait times for appointment
  - Takes values between 0 (low wait time) and 1 (high wait time)
- *Accessibility*
  - Travel distance to primary care providers, measured in miles

Interpretation

- An increase of 1% in lack of availability of primary care providers results in 0.0755 unit increase in log(ED cost PMPM) given all other predictors fixed
- A reduction of 1 mile in travel distance to primary care providers results in 0.002 unit increase in log(ED cost PMPM) given all other predictors fixed
- The correlation between the two measures is 0.696. If *Availability* is discarded from the model, *Accessibility* is not statistically significant.

Summary