

Week 12 - Modeling through Statsmodels, Sklearn

Customization vs Rapid Development

Building our own models is great!

- Understand the assumptions
- Get EXACTLY what you need

Unfortunately, it takes a LOT of time!

Statsmodels

Importing Statsmodels

We can import `statsmodels` in one of two ways:

1. With support for R-style formulas:

```
import statsmodels.formula.api as sm
```

2. Using pre-built numpy arrays as inputs:

```
import statsmodels.api as sm
```

We will focus on option (1) for now

Preparing a Dataset

When using formulas, we prepare our dataset by importing the data into a Pandas `DataFrame`. We should take care that each of our variables has a name with

1. **No spaces**
2. No symbols
3. Made up of letters and numbers (also can't have a number as the first character)

Preparing a Dataset

Our code so far might look something like:

```
import statsmodels.formula.api as sm
import pandas as pd, numpy as np

data = pd.read_csv("https://github.com/dustywhite7/Econ8320/blob/"
                  + "master/AssignmentData/assignment8Data.csv?raw=true")
```

Implementing a Model

The first thing we might try is a simple linear regression:

```
reg = sm.ols("hhincome ~ year", data=data).fit()  
print(reg.summary())
```

Or, I might want to try regressing year on the logged average household incomes:

```
reg = sm.ols("np.log(hhincome) ~ year", data=data).fit()  
print(reg.summary())
```

Advancing our Model

It might be useful to create state-level fixed effects by including dummy variables for the states in our `statefip` column.

```
reg = sm.ols("np.log(hhincome) ~ year + C(statefip)",  
             data=data).fit()  
print(reg.summary())
```

The `C()` command indicates that we would like to consider the `statefip` variable as a Categorical variable, not a numeric variable.

Additional Transformations

Sometimes we want to include transformed variables in our model:

```
# Square a variable using the I() function for  
# mathematical transformations  
reg = sm.ols("np.log(hhincome) ~ age + I(age**2)",  
             data=data).fit()
```

```
# Combine variables using the I() function for  
# mathematical transformations  
reg = sm.ols("np.log(hhincome) ~ I(age-education-5)",  
             data=data).fit()
```

Robust Modeling

If we want to utilize robust standard errors, we can update our regression results:

```
reg = sm.ols("np.log(hhincome) ~ year + C(statefip)",
             data=data).fit()
# Use White's (1980) Standard Error
reg.get_robustcov_results(cov_type='HC0')
print(reg.summary())

# -----

reg = sm.ols("np.log(hhincome) ~ year + C(statefip)",
             data=data).fit()
# Use Cluster-robust Standard Errors
reg.get_robustcov_results(cov_type='cluster',
                         groups=data['statefip']) # Need to specify groups
print(reg.summary())
```

Robust Modeling

Below are some of the [covariance options](#) that we have:

1. `HC0` : White's (1980) Heteroskedasticity robust standard errors
2. `HC1` , `HC2` , `HC3` : MacKinnon and White's (1985) alternative robust standard errors, with `HC3` being designed for improved performance in small samples
3. `cluster` : Cluster robust standard errors
4. `hac-panel` : Panel robust standard errors

Time Series Models

We have multiple time series options available.

- [ARIMA](#) models
- [VAR](#) models
- [Exponential Smoothing](#) models

Modeling Discrete Outcomes

If we have a binary dependent variable, we are able to use either [Logit](#) or [Probit](#) models to estimate the effect of exogenous variables on our outcome of interest. To fit a Logit model:

```
from scipy import stats
stats.chisqprob = lambda chisq,
                        df: stats.chi2.sf(chisq, df)
# Previous lines fix a temporary problem between
# statsmodels and scipy's chi square distribution

myformula="married ~ hhincome + C(statefip) + C(year) + educ"
model= sm.Logit.from_formula(myformula, data=data).fit()
```

Modeling Count Data

When modeling count data, we have options such as [Poisson](#) and [Negative Binomial](#) models.

```
from scipy import stats
stats.chisqprob = lambda chisq,
                    df: stats.chi2.sf(chisq, df)
# Previous lines fix a temporary problem between
# statsmodels and scipy's chi square distribution
data = pd.read_csv("auto-mpg.csv")

myformula="nchild ~ hhincome + C(statefip) + C(year) + educ + married"
model= sm.Poisson.from_formula(myformula, data=data).fit()
```

Patsy: Using Regression Equations

Why Use Patsy?

- We could just select our variables manually, and creating a column of ones is trivial (remember??)
- Patsy allows us to separate our endogenous and exogenous variables AND to
 - "Dummy out" categorical variables
 - Easily transform variables (square, or log transforms, etc.)
 - Use identical transformations on future data

Getting Started

```
import patsy as pt
import pandas as pd
import numpy as np

data = pd.read_csv("https://github.com/dustywhite7/Econ8320/blob/"
                  + "master/AssignmentData/assignment8Data.csv?raw=true")

# To create y AND x matrices
y, x = pt.dmatrices("hhincome ~ year + educ + married + age",
                  data = data)

# To create ONLY an x matrix
x = pt.dmatrix("~ year + educ + married + age",
               data = data)
```

These regression equations automatically include an intercept term.

Categorical Variables

```
# To create y AND x matrices  
eqn = "hhincome ~ C(year) + educ + married + age"  
y, x = pt.dmatrices(eqn, data = data)
```

Categorical variables can be broken out into binary variables using the `C()` syntax inside of the regression equation.

In this case, there would be binary variables for each unique value of `year`.

Transforming Variables

```
# To create y AND x matrices  
eqn = "I(np.log(hhincome)) ~ C(year) + educ + married + age + I(age**2)"  
y, x = pt.dmatrices(eqn, data = data)
```

We can transform variables using the `I()` syntax inside of the regression equation. We then use any numeric transformation that we choose to impose on our data.

In this case, we logged our dependent variable, `hhincome`, and added the square of our `age` term.

SUPER IMPORTANT → Same Transformation on New Data!

```
# To create a new x matrix based on our previous version  
xNew = pt.build_design_matrices([x.design_info], dataNew)
```

We can create a new matrix in the SAME SHAPE as our original `x` matrix by using the `build_design_matrices()` function in `patsy`.

We pass a list containing the old design matrix information, as well as the new data from which to construct our new matrix.

Why Does Recreating our `x` array Matter?

- Ensures that we always have the same number of categories
- Maintains consistency in our model
- Makes our work replicable
- Can streamline the use of `statsmodels` and `sklearn` in the same workflow

Using this method to create new samples from which we will make predictions is extremely valuable

scikit-learn

Predictive Modeling

What `statsmodels` does for regression analysis, `sklearn` does for predictive analytics and machine learning.

- Likely the most popular machine learning library today
- Has a standard API to make using the library VERY simple.

Decision Tree Classification (and Regression)

Classification and Regression Trees (CARTs) are the standard jumping-off point for exploring machine learning. They are very easy to implement in `sklearn`:

```
from sklearn import tree
from sklearn.metrics import accuracy_score

clf = tree.DecisionTreeClassifier()
clf = clf.fit(x, y)

pred = clf.predict(new_xs)

print(accuracy_score(new_ys, pred))
```


Support Vector Machines

We also implement [Support Vector Machines](#) for both [classification](#) and [regression](#):

```
from sklearn import svm
from sklearn.metrics import accuracy_score

clf = svm.SVC()
clf = clf.fit(x, y)

pred = clf.predict(new_xs)

print(accuracy_score(new_ys, pred))
```

Can you see the API pattern yet?

Random Forest Models

Again, available in both [classification](#) and [regression](#) flavors, these models are aggregations of many randomized Decision Trees.

```
from sklearn.ensemble import RandomForestClassifier
from sklearn.metrics import accuracy_score

clf = RandomForestClassifier(n_estimators=50)
clf = clf.fit(x, y)

pred = clf.predict(new_xs)

print(accuracy_score(new_ys, pred))
```

There MUST be a pattern here...

Data Preprocessing

Many other tools are also available to aid in the data cleaning process through `sklearn`.

Some of these are:

- [Principal Component Analysis \(PCA\)](#)
- [Factor Analysis](#)
- Many [Cross-Validation Algorithms](#)
- [Hyperparameter Tuning](#)
 - Finding the correct parameters for a decision tree or random forest, for example
- [Model Evaluation Tools](#)

Homework

Build an OLS regression and Random Forest using `statsmodels` and `sklearn` together with some data on the value of NFL franchises over time.

See Mimir for more details, and to submit your work.