Week 9 - 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)

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
from sqlalchemy import create_engine
import pandas as pd, numpy as np

engine = create_engine(
  'mysql+mysqlconnector://viewer:@dadata.cba.edu:3306/ACS'
          )

SELECT = """SELECT AVG(hhincome) AS hhincome, year,
    statefip
  FROM ACS
  GROUP BY year, statefip
  ORDER BY year, statefip"""

data = pd.read_sql(SELECT, engine)
```

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 **C**ategorical 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.

To implement an ARIMA(1,1,0) model:

```
from statsmodels.tsa.arima_model import ARIMA

y = data.loc[data['statefip']==31, ['hhincome','year']]
y.index=pd.to_datetime(y.year)
reg = ARIMA(y['hhincome'], order=(1,1,0)).fit()
print(reg.summary())
```

Time Series Models

To implement a VAR model:

```
from statsmodels.tsa.vector_ar.var_model import VAR

y = data.loc[data['statefip']==31, ['hhincome','year']]
y.index=pd.to_datetime(y.year)
reg = VAR(y['hhincome']).fit()
print(reg.summary())
```

The VAR model will optimize its own order (number of lags included) based on information criteria estimates.

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
data = pd.read_csv("auto-mpg.csv")
data['highMPG'] = (data['mpg']>30).astype(np.int)

myformula="highMPG ~ cylinders + displacement + weight"
model= sm.Logit.from_formula(myformula, data=data).fit()
```

Modeling Discrete Outcomes

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="mpg ~ cylinders + displacement + weight"
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
- 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("wagePanelData.csv")

# To create y AND x matrices
y, x = pt.dmatrices("LWAGE ~ TIME + EXP + UNION + ED",
                    data = data)

# To create ONLY an x matrix
x = pt.dmatrix("~ TIME + EXP + UNION + ED",
                    data = data)
```

These regression equations automatically include an intercept term.

Categorical Variables

```
# To create y AND x matrices
eqn = "LWAGE ~ C(ID) + TIME + EXP + UNION + ED + C(OCC)"
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 `ID` and `OCC`.

Transforming Variables

```
# To create y AND x matrices
eqn = "I(np.log(LWAGE)) ~ C(ID) + TIME + EXP + I(EXP**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, `LWAGE`, and squared the `EXP` term.

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 Design Info Matter?

- Ensures that we always have the same number of categories
- Maintains consistency in our model
- Makes our work replicable

Using this method to create new datasets from which to generate 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.pred(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.pred(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=100)
clf = clf.fit(x, y)

pred = clf.pred(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`