

# 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

Let's make statistics in Python easy!

# 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 smf
import pandas as pd, numpy as np

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

# Regression Equations

`statsmodels` incorporates `R`-style regression equations by using the `patsy` library behind the scenes:

```
independent variable ~ dependent variable + another  
dependent variable + any other dependent variables
```

# Implementing a Model

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

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

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

```
reg = smf.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 = smf.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 = smf.ols("np.log(hhincome) ~ age + I(age**2)",  
              data=data).fit()
```

```
# Combine variables using the I() function for  
# mathematical transformations  
reg = smf.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 = smf.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())
```

# More robust modeling

```
reg = smf.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:

```
import statsmodels.api as sm

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.

```
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

Breaking out our 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

# Why use `patsy` when `statsmodels` handles it for us?

By breaking out our regression equations, we can use the same data splits and processing steps for both `statsmodels` and for `sklearn` (which does not use `patsy` )!

# 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
- AGAIN - ❤️ streamlines the use of `statsmodels` and `sklearn` in the same workflow ❤️



# scikit-learn

see  learn

learn, , 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

**Lab time!**