This is the read me file for using the data to replicate "Vertical Arrangements, Market Structure, and Competition: An Analysis of Restructured U.S. Electricity Markets." There are two folders as the paper uses two software packages: Stata and AMPL.

### Description of Stata do file and input files

In the Stata directory, you will find the BMS_calculations.do file. It is set up to replicate all of the results from the paper that were calculated in Stata. Simply edit the file to direct Stata to search for the data files in the same directory that you have put the do file and data, e.g., C:\data\3market\AER\200507_data\Stata_data. Then, assuming you have Stata installed, you can simply run the do file and it will replicate all of the results of the paper that were calculated in Stata.

Detailed descriptions of the variables and the contents of each data file are included in the do file.

### Description of AMPL model and inputs

The Cournot equilibria for each market is calculated using a model written in AMPL. Information on AMPL can be found at http://www.ampl.com/. AMPL takes as inputs a model file, here denoted by the suffix .mod, and a data file, here denoted with the suffix .txt.

The simulation inputs are organized by market, cal, ne, and pjm. Each market has a .mod file representing the model and 4 .txt files, one each for each of the months simulated.

In each folder, the .txt files contain the parameter values utilized by the .mod file when solving for an equilibrium. These parameters are described below.

#### Parameter and variable definitions in .mod files

```
set FIRMS;                  # indexes firms in the simulation
set TFIRMS;                 # defines thermal only firms
set THERMLINE;                  # indexes the segments of the piecewise linear cost
curve for each firm
```

The following parameters are used to index time (hours) and allow flexibility in the number (and identity) of hours simulated

```
param BT> 0;                # timestamp for first hour
param Tdata integer > 0;    # Max number of hours
param ST integer <= 1000;   # starting hour
param T integer <= 1000;       # number of time periods
param BOOT_RUN <= 100;         # individual bootstrap iteration
```

The following parameters are used to define firm level characteristics

param firmtype        # fringe if < 2, Cournot if 2

param k         # Intercept of marginal cost by cost segment

param mc             # Slope of marginal cost by cost segment
param maxtherm           # Maximum capacity by firm and cost segment
param qmr             # must-run quantity by firm - not included in maxtherm

param a_hat    # actual total demand
param b        # slope of demand curve
param contractpct  # percentage of actual demand that is under vertical obligation
param p_act    # actual hourly market price
param q_act          # actual hourly residual market quantity
param perturb        # param used to perterb contract position


The following variables are calculated by the simulation

var a            # hourly intercept of demand curve
var q          # Firm level hourly TOTAL quantity
var qth         #Firm level hourly quantity by cost segement
var qc         #Firm level hourly vertical commitment
var psi          # Dual on thermal capacity by segment and hour
var p                   # market price
var TC         # Hourly Total production cost by Firm

#### data values in the .txt files

Each .txt file contains the specific parameter values described above.

Ampl can read data values in a vector or matrix format.

For example, simple parameters are defined in a single line, such as

param   firmtype :=      AES 2 DUKE 2 DYN 2 MIR  2 REL 2 FR  1    ;

Other multi-dimensional parameters are defined in matrix format, such as:

```
param   k :           AES       DUKE     DYN      MIR      REL      FR    :=

1       26.2763 26.5773 24.7009 26.8462 24.5551 27.7583
2       26.7315 30.1448 26.4688 27.0669 25.6456 31.8488
3       27.2973 34.7421 28.7443 28.3748 26.7952 34.2444
4       29.3533 47.8607 31.1763 29.0793 27.2972 35.0448
5       30.7142 51.1298 53.8800 35.0739 34.2566 38.9966
;
```

In some cases, such as production costs, values change monthly, and

a new .txt file is used for each month.   In other cases, such as
market quantity, values change hourly.

#### Solution commands in the .run files

The .run files contain batch solution commands for solving multiple
problems.  The program can be set to iterate through individual or
groups of multiple hours.  In the case of the provided .run files, the
batch program also iterates through multiple perterbations of ther vertical
position (contractpct) of each firm.

The .run file also specifies the simulation output through use of the
ampl "display" command.


The remainder of the .mod file contains the equilibrium conditions to be
solved for.  The specific conditions can depend upon the market - for example
the California model contains no contractpct component.




price-caps - in order to represent price caps in the eastern markets, equilibrium prices
were truncated at 1000 in both PJM and New England in the results.  In most cases, the
equilibrium price was allowed to rise above the capped level in the simulation, but was
reset to the capped level for reporting results.

For purposes of calculating firm production quantities, more detail about an equilibrium
at the price cap was needed.  For the case of PJM with no vertical arrangements and the
log-linear residual demand specification, a large fringe production capacity with marginal
cost of 1000.01 was added to the supply data.  The presence of this fictional fringe
capacity effectively created a horizontal residual demand curve at the capped price.
Simulated equilibrium prices for this case never rise above 1000.01.