```
$ontext
Title:   PJM_10node_conjecture.gms
References: Y. Chen and B.F. Hobbs, "An Oligopolistic Power Market with
          NOx Tradable Permits," IEEE Transactions on Power System,
          20(1): 119-120, 2005
Author:  Yihsu Chen, The Johns Hopkins University
Content: The code is writen for PJM electricity market model. In this model,
        some generators are assumed to exercise Cournot strategy in elec.
        market, while also allowing to exercise conjectured price response in
        NOx permit market. They are represented by st(f), and rpc(f), respec-
        tively, in the model.  The NOx cap is represented as a constraint, and
        SO2, acid rain title 4, is represented by multipling with SO2 permit
        price in supply curve.
Output:  ps.txt: producer surplus, nox trade, firm total sale, gen. cost, tot
        nox in OTC cap, tot NOx and firm capacity share
        ts_lcp.txt:  total sale of firm f at i node
        x_lcp.txt: individual generator output level
        pe_lcp.txt: price level of i at t period
        flow_lcp.txt: flow in the arcs
        w_lcp.txt: wheeling charge
        y_lcp.txt: outflow from node i
        pn_lcp.txt: permit price, tot OTC NOx and tot.NOx
Remark:  While rpc(f)=0 for all firms, the model reduces to "no conjectur price"
        While, in addition, st(f)=0 for all firms, the model reduces to perfect
        competition.
Paper:   "An Oligopolistic Energy Market Model with Tradable NOx permits", by
        Yihsu Chen and Benjamin F. Hobbs
$offtext
$inlinecom/* */
set
h plant index /1*879/
i node /ME1,ME2,PPL1,BGEPEP,PPL2,DPL,PE,PS,AE,PPL3,JC1,JC2,BGE2,PN/
f firm /1*9/
t time period /1*5/
k lines /1*18/
ll /up,lo/
p(f,i,h) plant dynamic set
a attributs /SCAP,COST,NOX,SO2,OTC,PCAID,OWNERID,ARAIN,MAXOfRes/;
$include c:\My Stuffs\My
Research\IEEE\Model\Revised\Data_10node_network_conj_1208_revised.txt
*$include g:\ieee\Data_10node_network_conj_1208.txt
qnox(f)=qnox(f)*0.8; /* 80% of permit used for compliance */
table
d(h,a) plant h
$include c:\My Stuffs\My
Research\IEEE\Model\Revised\Data_10node_plant_res_revised.txt
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```
*$include g:\ieee\Data_10node_plant_res.txt
;
*Define dynamic set*
p(f,i,h)=yes$(d(h,"PCAID")=ord(i) and d(h,"OWNERID")=ord(f));

parameter
cap(i) total cap in node
fcap(f) firm capacity
e(f,i,h) emission rate
c(f,i,h) variable cost
st(f) strategy index /1 0,2 0,3 0,4 0,5 0,6 0,7 0,8 0,9 0/
npc(f) conjecture price slpe /1 0,2 0,3 0,4 0,5 0,6 0,7 0,8 0,9 0/
fc(f,i,t) forward contract amount
rm reserve margin /0.075/;
**calculation**
e(f,i,h)$p(f,i,h)=d(h,"nox")/2000;
cap(i)=sum(p(f,i,h),d(h,"SCAP"));
c(f,i,h)$p(f,i,h)=d(h,"cost")+140*d(h,"SO2")*d(h,"arain");
fcap(f)=sum(h$(d(h,"OWNERID")=ord(f)),d(h,"SCAP"));

fc(f,i,t) = ffc(i,f)*load(i,t);
*fc(f,i,t) =0;



variables
y(i,t)  flow from hub to n at t period
ts(i,t) total s in n at period t
w(i,t)  wheeling charge from hub to n at t period
theta(f,t) dual of f firm's s at t period
pe(i,t) price of power
fnox(f) firm nox emission
flow(k,t) flow
totn(f) total nox
aa(i,t) arbitrage
ph(t) hub price
sps(i,t) spot sales;


*aa.fx(i,t)=0;
positive variables
x(f,i,h,t) output of p plant in t period
s(f,i,t) s of firm f at node n in t period
rho(f,i,h,t) dual of plant h cap
lambda_m(k,t) dual of ptdf lower
lambda_p(k,t) dual of ptdf upper
```

```
pn price of permits
r(f,i,h,t) reserve capacity
eta(f,i,h,t) dual of reserve
pr(t) price of reserve;

equations
f1(f,i,t) cp for s
f2(f,i,h,t) cp for x
f3(f,i,h,t) cp for rho
f4(f,t) cp for theta
g1(i,t) cP for y
g2(k,t) cp for ptdf negative lambda_n
g3(k,t) cp for ptdf positive lambda_p
mc1(i,t) market clearing for power
mc2 cp for pn
df1(i,t) price of electricity
df2(f) firm total NOx emission
df3(i,t) total sales
df4(k,t) flow
g4(f,i,h,t) cp for r
g5(f,i,h,t) cp for eta
mc4(t) market clearning for reserve
a1(i,t) arbitrage
a2(t) sum equal to zero
df5(i,t) spot sales;

f1(f,i,t).. -pe(i,t)+w(i,t)+(p0(i,t)/q0(i,t))*(s(f,i,t)-fc(f,i,t))$st(f)+theta(f,t)=g=0;
f2(f,i,h,t)$p(f,i,h).. c(f,i,h)-w(i,t)+[pn+npc(f)*(fnox(f)-
qnox(f))]*e(f,i,h)$(d(h,"otc")=1)+rho(f,i,h,t)/b(t)-theta(f,t)=g=0;
f3(f,i,h,t)$p(f,i,h).. -x(f,i,h,t)-r(f,i,h,t)+d(h,"scap")=g=0;
f4(f,t).. sum(p(f,i,h),x(f,i,h,t))-sum(i,s(f,i,t))=e=0;
g1(i,t).. b(t)*w(i,t)+sum(k,ptdf(k,i)*(lambda_p(k,t)-lambda_m(k,t)))=e=0;
g2(k,t).. flow(k,t)+lcap(k,"lo")=g=0;
g3(k,t).. -flow(k,t)+lcap(k,"up")=g=0;
mc1(i,t).. y(i,t)=e=sum(p(f,i,h),x(f,i,h,t))+z(i,t)-sum(f,s(f,i,t))-aa(i,t);
mc2..   sum(f,qnox(f))-sum(f,fnox(f))=g=0;
df1(i,t).. pe(i,t)=e=p0(i,t)-(p0(i,t)/q0(i,t))*(ts(i,t)+aa(i,t));
df2(f).. fnox(f)=e=sum((p(f,i,h),t)$(d(h,"otc")=1),x(f,i,h,t)*b(t)*e(f,i,h));
df3(i,t).. ts(i,t)=e=sum(f,s(f,i,t));
df4(k,t).. flow(k,t)=e=sum(i,ptdf(k,i)*y(i,t));
g4(f,i,h,t)$p(f,i,h)..-pr(t)*b(t)+rho(f,i,h,t)+eta(f,i,h,t)=g=0;
g5(f,i,h,t)$p(f,i,h).. -r(f,i,h,t)+d(h,"scap")*d(h,"MAXOfRes")=g=0;
mc4(t)..sum(p(f,i,h),r(f,i,h,t))- sum(i,ts(i,t))*rm =g=0;
a1(i,t).. pe(i,t)-w(i,t)=e=ph(t);
a2(t).. sum(i,aa(i,t))=e=0;
df5(i,t).. sps(i,t)=e=ts(i,t)-sum(f,fc(f,i,t));
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```
model conj
/f1.s,f2.x,f3.rho,f4,g1,g2.lambda_m,g3.lambda_p,mc1,mc2.pn,df1,df2,df3,df4,g4.r,g5.eta
,mc4.pr,a1,a2,df5/;
conj.optfile=1;
solve conj using MCP
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