```
$TITLE  M8-6b.GMS: 2x2x2 of M8-6a in set notation

TABLE BENCH(*,*)
     XHH  YHH  XHF  YHF  XFF  YFF  XFH  YFH   UH   UF   CONSH CONSF
PXH  150       -50                       -100
PYH        50                       50  -100
PXF             50         50                 -100
PYF                             150      -50  -100
PUH                                       200       -200
PUF                                            200        -200
PLH  -120 -10                                             130
PKH   -30 -40                                              70
PLF                       -40  -30                          70
PKF                       -10 -120                         130;

DISPLAY BENCH;

SETS I goods     /1, 2/
     J factors   /1, 2/
     C countries /H, F/;

ALIAS (J,JJ), (I,II);

PARAMETERS

 VS(J,C)       endowment of factor j in country c
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 TC(I)          trade cost of importing good i for country c
 BETA(I,J)      share of factor j in the production of good i
 GAMMA(I)       share of good i in the utility function
 WELW(C)        welfare weight of country c in world welfare
 RESULTS(*,*)   assemble the results;

VS("1", "H") = BENCH("PLH", "CONSH");
VS("2", "H") = BENCH("PKH", "CONSH");
VS("1", "F") = BENCH("PLF", "CONSF");
VS("2", "F") = BENCH("PKF", "CONSF");

BETA("1","1") = -BENCH("PLH", "XHH")/ BENCH("PXH", "XHH");
BETA("1","2") = -BENCH("PKH", "XHH")/ BENCH("PXH", "XHH");
BETA("2","1") = -BENCH("PLH", "YHH")/ BENCH("PYH", "YHH");
BETA("2","2") = -BENCH("PKH", "YHH")/ BENCH("PYH", "YHH");

GAMMA("1")    = -BENCH("PXH", "UH")/ BENCH("PUH", "UH");
GAMMA("2")    = -BENCH("PYH", "UH")/ BENCH("PUH", "UH");

WELW("H") = BENCH("PUH", "UH")/(BENCH("PUH", "UH")+BENCH("PUF", "UF"));
WELW("F") = BENCH("PUF", "UF")/(BENCH("PUH", "UH")+BENCH("PUF", "UF"));

DISPLAY VS, BETA, GAMMA, WELW;

TC(I)    = 1.0001;
```

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VARIABLES
  JWELMAX         joint welfare maximization
  WELMAXH         welfare of country H
  WELMAXF         welfare of country F
  TR(I,C)         tariff of country C on good I;

POSITIVE VARIABLES
        X(I,C)    Activity level for prduction of I by C
        M(I,C)    Activity level for imports of I by C
        E(I,C)    Activity level for exports of I by C
        U(C)      Activity level for sector U in country C

        PX(I,C)   Price of commodity I in country C
        PW(I)     World price of commodity I
        PV(J,C)   Price of factor J in country C
        PU(C)     Price of welfare (expenditure function) in country C

        CONS(C)   Aggregate income;

EQUATIONS
        OBJJ
        OBJH, OBJF
        PRX(I,C)    Zero profit for sector I in country J
        PRM(I,C)    Zero profit for imports of I by country j
        PRE(I,C)    Zero profit for exports of I by country j
        PRU(C)      Zero profit for sector U
```

```
         MKX(I,C)   Supply-demand balance for commodity I
         MKW(I)     Supply-demand balance for imports and exports of I
         MKV(J,C)   Supply-demand balance for primary factor V1
         MKU(C)     Supply-demand balance for welfare (aggregate demand)

         ICONS(C)  Income definition for CONS;

OBJJ..       JWELMAX =E= PROD(C, U(C)**WELW(C));

OBJH..       WELMAXH =E= U("H");
OBJF..       WELMAXF =E= U("F");

*       Zero profit inequalities

PRX(I,C)..  PROD(J, PV(J,C)**BETA(I,J))  =G=  PX(I,C);

PRM(I,C)..  PW(I)*TC(I)*TR(I,C)  =G=  PX(I,C);

PRE(I,C)..  PX(I,C)  =G=  PW(I);

PRU(C)..    PROD(I, PX(I,C)**GAMMA(I)) =G=  PU(C);

*       Market clearance inequalities

MKX(I,C)..  X(I,C)- E(I,C) + M(I,C)/TC(I) =G=
```

```
            PROD(II, PX(II,C)**GAMMA(II))*(GAMMA(I)/PX(I,C))*U(C);

MKW(I)..    SUM(C, E(I,C) - M(I,C)) =G= 0;

MKV(J,C)..  VS(J,C)  =G=  SUM(I,
            PROD(JJ, PV(JJ,C)**BETA(I,JJ))*(BETA(I,J)/PV(J,C))*X(I,C));

MKU(C)..    U(C) =E= CONS(C) / PU(C);

*       Income balance equations

ICONS(C)..  CONS(C) =E= SUM(J, VS(J,C)*PV(J,C)) +
                        SUM(I, PW(I)*(TR(I,C) - 1)*M(I,C));

MODEL MCP /PRX.X, PRM.M, PRE.E, PRU.U,
                MKX.PX, MKW.PW, MKV.PV, MKU.PU,
                ICONS.CONS/;

MODEL MPEC /OBJJ, OBJH, OBJF, PRX.X, PRM.M, PRE.E, PRU.U,
                MKX.PX, MKW.PW, MKV.PV, MKU.PU,
                ICONS.CONS/;

PU.L(C) = 1;
PU.FX("H") = 1;

*       Set initial values of variables:
```

```
X.L(I,C)        =100;
M.L(I,C)        =100;
E.L(I,C)        =100;
U.L(C)          =200;
PX.L(I,C)       =1;
PW.L(I)         =1;
PV.L(J,C)       =1;
PV.L(J,C)       =1;
CONS.L(C)       =200;
WELMAXH.L       =U.L("H");
WELMAXF.L       =U.L("F");
JWELMAX.L       = 1;

* fix tariffs at zero (meaning TR = 1) to solve for free trade

TR.FX(I,C) = 1;

OPTION MPEC = nlpec;
SOLVE MPEC USING MPEC MAXMIZING JWELMAX;

RESULTS("WELJ", "FREETR") = JWELMAX.L/200;
RESULTS("WELH", "FREETR") = U.L("H")/200;
RESULTS("WELF", "FREETR") = U.L("F")/200;
RESULTS("TARIFFH", "FREETR") = TR.L("2","H")-1;
RESULTS("TARIFFF", "FREETR") = TR.L("1","F")-1;
```

```
DISPLAY RESULTS;

* show that this can be done with the mcp version when TR variables
* are fixed

SOLVE MCP USING MCP;
TR.FX(I,"H") = 1.2;
SOLVE MCP USING MCP;

* solve for the optimal tariff for country h when TRF is still fixed
* at zero.

TR.UP("2", "H") = +INF;
TR.LO("2", "H") = -INF;

SOLVE MPEC USING MPEC MAXIMIZING WELMAXH;

RESULTS("WELJ", "UNIH") = JWELMAX.L/200;
RESULTS("WELH", "UNIH") = U.L("H")/200;
RESULTS("WELF", "UNIH") = U.L("F")/200;
RESULTS("TARIFFH", "UNIH") = TR.L("2","H")-1;
RESULTS("TARIFFF", "UNIH") = TR.L("1","F")-1;
DISPLAY RESULTS;

*$EXIT
```

```
SETS K iterative procedure to determine Nash tariffs /K1*K10/;

TR.FX(I,C) = 1;

LOOP(K,

TR.UP("2", "H") = +INF;
TR.LO("2", "H") = -INF;
TR.FX("1", "F") = TR.L("1", "F");

SOLVE MPEC USING MPEC MAXIMIZING WELMAXH;

TR.UP("1", "F") = +INF;
TR.LO("1", "F") = -INF;
TR.FX("2", "H") = TR.L("2", "H");

SOLVE MPEC USING MPEC MAXIMIZING WELMAXF;

);

RESULTS("WELJ", "NASH") = JWELMAX.L/200;
RESULTS("WELH", "NASH") = U.L("H")/200;
RESULTS("WELF", "NASH") = U.L("F")/200;
RESULTS("TARIFFH", "NASH") = TR.L("2","H")-1;
RESULTS("TARIFFF", "NASH") = TR.L("1","F")-1;
DISPLAY RESULTS;
```

```
$LIBINCLUDE XLDUMP RESULTS M8.XLS SHEET2!A3
```