

## Scheduling Example – Farm Planning

- GAMS model similar to the PC/LP model used for the Top Crop Farmer Workshop
  - | Goal – schedule machinery and land resources
  - | Q: Why is scheduling important?
  - | A: Efficiency in resource use translates into higher profits for the producer

## Farm Planning Example (cont'd.)

- Model Uses
  - | Allows producer to develop a rough operational plan
  - | Allows user to ask “what if” questions about expanding the resource base (rent or buy land/machines), or to see how a “new crop” would fit into the current system
  - | Allows policy analysts to simulate producer responses to alternative policies

## Farm Planning Example (cont'd.)

### I Critical features:

- I Corn is the only crop grown
- I Crop yields are sensitive to planting and harvesting dates
  - Adjustment to yield due to timing is captured through a parameter – YIELD(PPER,HPER)
- I Machinery resources are scarce enough that several potential bottlenecks can occur

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## Farm Planning Example (cont'd.)

- I This is scheduling over time – periods are on the order of 2-3 weeks in length and of variable length
  - I This length of period (problem specific) is selected compromise between
    - Having the time periods so short that the randomness of weather will regularly override any plan, or
    - Having the time periods so long that resource bottlenecks cannot be identified

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## Farm Planning Example (cont'd.)

- SETS
- PER Periods /MARAPR,APR3,APR4,MAY1,MAY2,MAY3,  
MAY4,MAYJ,JUN1,JUN2,JUN3, JUNJLY,JULY,  
JYAUG,AUGSP,SEP4,OCT1,OCT2,NOV1,NOV2/
- \* The periods are defined as follows:
- \* MARAPR:Mar 1-Apr 21; APR3:Apr 22-25; APR4:Apr 26-May 2
- \* MAY1:May 3-9; MAY2 :May 10-16; MAY3:May 17-23
- \* MAY4:May 24-30; MAYJ:May 31-Jun 6; JUN1:Jun 7-13
- \* JUN2:Jun 14-20, JUN3:Jun 21-27; JUNJLY:Jun 28-Jul 4
- \* JULY:Jul 5-Jul 11;JYAUG:Jul12-Aug29; AUGSP:Aug 30-Sep19;
- \* SEP4:Sep 20-26; OCT1:Sep 27-Oct 10
- \* OCT2:Oct11-31;NOV1:Nov1-21;NOV2:Nov 22-Dec 5

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## Farm Planning Example (cont'd.)

- Only some of these periods are suitable for
  - | Planting
  - | Harvesting
- SETS
- PPER(PER) Planting periods
- /APR3,APR4,MAY1,MAY2,MAY3,MAY4,MAYJ/
- HPER(PER) Harvesting periods
- /SEP4,OCT1,OCT2,NOV1,NOV2/ ;

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## Farm Planning Example (cont'd.)

- Hours available per period for field work are reflected in several parameters:
  - | Tractor – a scalar denoting the number of tractors
  - | HrsPerDayT – a scalar denoting the number of hours the tractor can be run per day
  - | Days(Per) – a parameter denoting the number of days available for field work by period
  - | CombRhs(Hper) – a parameter denoting the number of hours the combine is available by period

## Farm Planning Example (cont'd.)

- Three things must be scheduled in this example:
  - | Plowing the field to prepare for planting
  - | Planting the corn which must occur after plowing
  - | Harvesting the corn

## Farm Planning Example (cont'd.)

- Our problem variables are:
  - | VARIABLE NETREV Total net revenue ;
  - | POSITIVE VARIABLES
  - | \* The following variables are in units of acres.
  - | PLOW(Per) Acres plowed in period per
  - | ACRE(Per,Per) Acreage on Pper-Hper sched. ;
- Why is PLOW indexed only by the period when plowing occurs, but ACRE is indexed by both planting period and harvest period?

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## Farm Planning Example (cont'd.)

- PLOW(Per): It does not matter when the plowing is done as long as it is prior to planting
- ACRE(Pper,Hper): The schedule of planting and harvesting determines yield – so, it is not possible to independently schedule planting and harvesting without losing important information

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## Farm Planning Example (cont'd.)

- Model equations include the following:

- EQUATIONS

- OBJECTIVE Objective function (net revenue)
    - LAND Land availability constraints
    - TRACTR(Per) Tractor constraints in planting pers
    - SEQ(Per) Sequencing of plowing and planting
    - HARVEST(Per) Combine constraints in harvest pers

## Farm Planning Example (cont'd.)

- OBJECTIVE..

- $NETREV = E = \text{Sum}((P_{Per}, H_{Per}) \$Yield(P_{Per}, H_{Per}),$
  - $(Yield(P_{Per}, H_{Per}) * Price - P\_H\text{Cost})$
    - $*ACRE(P_{Per}, H_{Per})) ;$

- Notice that the logical value of  $Yield(P_{per}, H_{per})$  is used to suppress un-useful variables
    - Price denotes the price of corn
    - $P\_H\text{Cost}$  denotes the variable costs of production

## Farm Planning Example (cont'd.)

- LAND..
  - $\text{Sum}((P_{\text{Per}}, H_{\text{Per}}) \$ \text{Yield}(P_{\text{per}}, H_{\text{per}}), \text{ACRE}(P_{\text{Per}}, H_{\text{Per}}))$
  - $=L= \text{LandRhs};$
- 
- This constraint simply restricts the use of land to be no greater than the available land
  - Note this constraint is static – it would not be appropriate if several crops could be grown on the same piece of land during the year

## Farm Planning Example (cont'd.)

- Usage of the tractor resources must be scheduled
  - ┆ Available tractor time has been addressed  
( $\text{Tractor} * \text{HrsPerDay} * \text{Days}(\text{PER})$ )
  - ┆ Usage of tractors for different operations is reflected in three scalars:
    - $\text{PlwTrac}$  – hours per acre to plow
    - $\text{PltTrac}$  – hours per acre to plant
    - $\text{HavTrac}$  – hours per acre to harvest

## Farm Planning Example (cont'd.)

- $\text{TRACTR}(\text{Per}) ..$
  - $\text{PlwTrac} * \text{Plow}(\text{Per}) +$
  - $\text{Sum}(\text{HPer}\$\text{Yield}(\text{Per}, \text{Hper}), \text{PltTrac} * \text{ACRE}(\text{Per}, \text{HPer})) +$
  - $\text{Sum}(\text{PPer}\$\text{Yield}(\text{PPer}, \text{Per}), \text{HavTrac} * \text{ACRE}(\text{PPer}, \text{Per}))$
  - $=L= \text{Tractor} * \text{HrsPerDay} * \text{T} * \text{Days}(\text{PER}) ;$
- This constraint restricts uses of tractor hours not to exceed available tractor time
  - This constraint is dynamic with use and availability varying by period

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## Farm Planning Example (cont'd.)

- $\text{SEQ}(\text{Per}) ..$
  - $\text{Sum}(\text{Period}\$(\text{ord}(\text{Period}) \text{le } \text{ord}(\text{Per})), \text{PLOW}(\text{Period}))$
  - $=G= \text{Sum}(\text{PPer}\$(\text{ord}(\text{PPer}) \text{le } \text{ord}(\text{Per})),$
  - $\text{Sum}(\text{HPer}\$\text{yield}(\text{PPer}, \text{HPer}), \text{ACRE}(\text{PPer}, \text{HPer}))) ;$
- This constraint enforces the sequencing of plowing and planting (Note that Period and Per are aliases)
  - The left-hand side is an expression for the number of acres plowed from the beginning of the planning horizon through period Per

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## Farm Planning Example (cont'd.)

- $SEQ(Per) ..$
- $Sum(Period$(ord(Period) le ord(Per)),PLOW(Period))$
- $=G= Sum(PPer$(ord(PPer) le ord(Per)),$
- $Sum(HPer$yield(PPer,HPer),ACRE(PPer,HPer))) ;$
  
- The right-hand side is an expression for the cumulative number of acres planted from the beginning of the planning horizon through period Per
  
- The cumulative nature of these constraints is typical of sequencing constraints

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## Farm Planning Example (cont'd.)

- $HARVEST(HPer) ..$
- $Sum(PPer$Yield(Pper,Hper), Comb*ACRE(PPer,HPer))$
- $=L= CombRhs(HPer) ;$
  
- This constraint limits the use of the combine resource in period HPer to no more than the available amount of combine time
  
- This equation is generated only if  $yield(pper,hper)$  is strictly positive for some pper

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## Farm Planning Example (cont'd.)

### I Stochastic elements ignored:

I Yield/price variability

I Resource availability

- Bad weather can prevent field operations
- Machines may break
- Workers may not show up

## Farm Planning Example (cont'd.)

I The goal is profit maximization

I Some activities must be sequenced

- Plowing precedes planting
- Planting precedes harvesting

I Limitations on resources may be

- Static (Land)
- Dynamic (Tractor, Harvester)

## Other Dynamic Models – Optimal Growth

- Investment is also a process that occurs over time
  - | Investment produces new capital stock
  - | New capital stock does not appear instantly
- Depreciation is the gradual (i.e., over time) decay of the productive capacity of capital stock

## National Energy Planning Model

- **ETA-Macro Model** (Manne – etamac.gms in GAMS library)
  - | **E**nergy **T**echnology **A**ssessment (an engineering process based model of energy technology)
  - | **M**acro (a simple macro model)
  - | Used for forecasting energy supplies/demands over time

## ETA-Macro (cont'd.)

- Time horizon -- 1990-2030 (5-year periods)
- Economy-wide objective -- maximize the discounted utility of consumption over time
  - ┆ Utility is logarithmic and a fixed discount rate is used
  - ┆ Consumption is the residual after investment (in energy technologies) and energy expenses

## ETA-Macro (cont'd.)

- Dynamic features
  - ┆ Capacity expansion is irreversible
  - ┆ Investment drives capacity expansion
  - ┆ Substitution possibilities are limited for installed capacity, but flexible for capacity additions (putty/clay)
  - ┆ Depreciation of installed capital

## ETA-Macro (cont'd.)

- Discounted sum of utility of consumption:

$$\sum_{t=1}^T \beta^t u_t(C_t) = \sum_{t=1}^T \beta^t \ln(C_t)$$

- Simple macro relationship between consumption and production:

$$C_t = Y_t - I_t - EC_t$$

- (Consumption = GDP – Investment – Energy Costs)

## ETA-Macro (cont'd.)

- “Vintaged” production inputs/outputs (putty/clay formulation)

- ┆ All inputs to production (capital, labor, electric energy and non-electric energy) are vintaged:

- $k_t = kn_t + k_{t-1}(1-dep)$
- $l_t = ln_t + l_{t-1}(1-dep)$
- $e_t = en_t + e_{t-1}(1-dep)$
- $n_t = nn_t + n_{t-1}(1-dep)$

## ETA-Macro (cont'd.)

| Output is also vintaged

- $y_t = yn_t + y_{t-1}(1-dep)$

| The new vintage output is a function of new vintage inputs according to the following relationship:

$$yn_t = A \left[ \gamma_{kl} (kn_t^\alpha ln_t^{1-\alpha})^{-\rho} + \gamma_{en} (en_t^\beta nn_t^{1-\beta})^{-\rho} \right]^{-1/\rho}$$

| (Initial stocks are given for output and inputs)

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## ETA-Macro (cont'd.)

| ETA

| Leontief production is used to describe energy production possibilities in the full model

| Here, exogenous price schedules are given with non-electric energy prices growing faster than electric energy prices

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