Economic decision analysis: Concepts and applications

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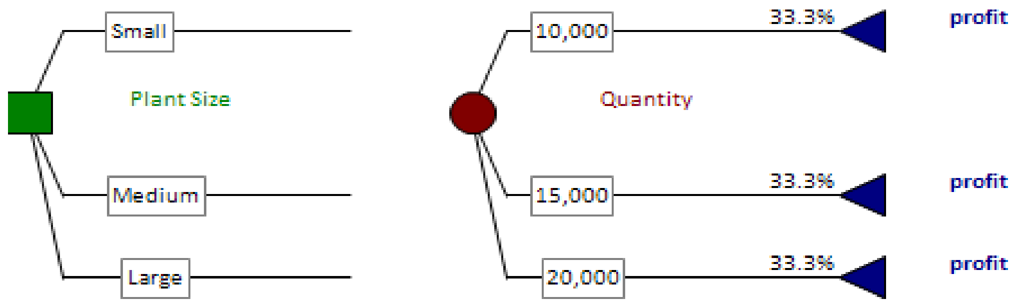
My background and this work

- Education in DA and Economics
- Government and industry consulting
- Portfolio DA
- The nature of modeling

Textbook DA problem: plant size vs. and sales volume

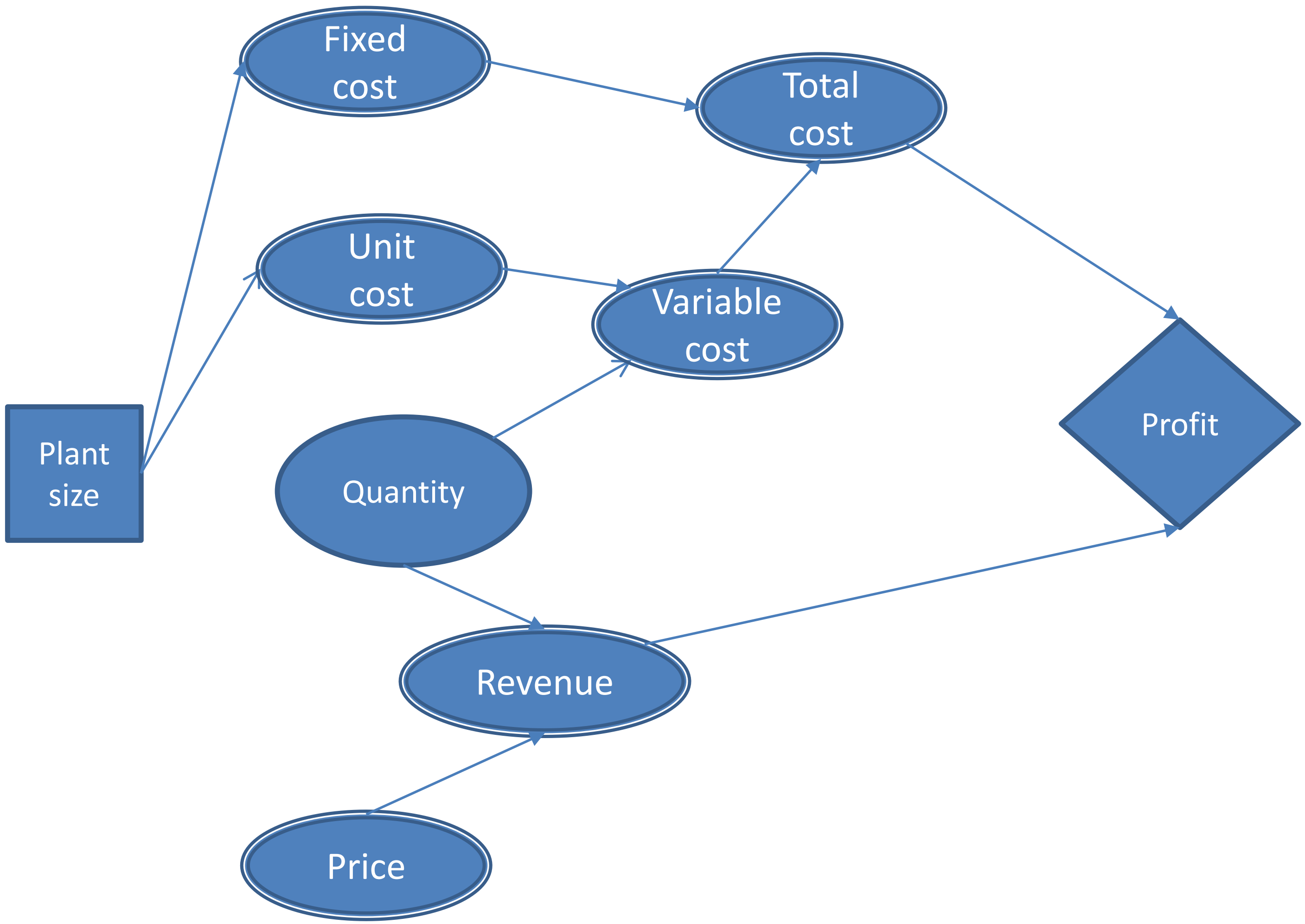


Profit =
quantity * (100 - variable cost) - fixed cost

Plant size	Fixed cost	Variable cost per unit
Small	$75,000	$70
Medium	$325,000	$50
Large	$650,000	$30

		TOTAL PROFIT		
Quantity	Probability	Small plant	Medium plant	Large plant
10,000	33%	$225,000	$175,000	$50,000
15,000	33%	$375,000	$425,000	$400,000
20,000	33%	$525,000	$675,000	$750,000
Expected value		$375,000	**$425,000**	$400,000

The influence diagram serves as a map for constructing the model

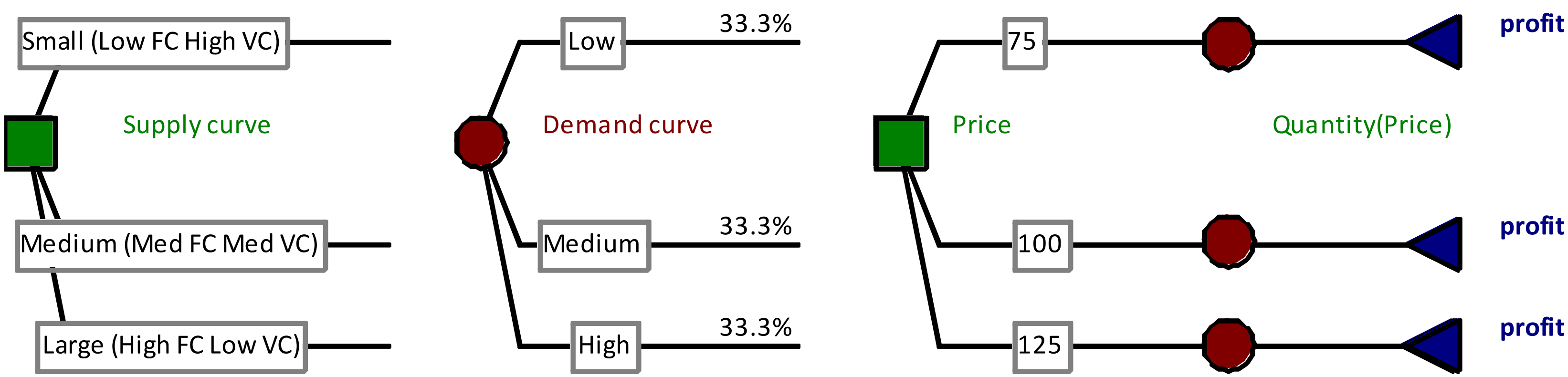


Is price a decision □ or uncertainty ○? What about quantity?

- "We will have the highest profit margin and the highest volume." [P] [Q]
- "What we make is what we will sell." (P) [Q]
- "If our customer's price drops, we'll have to suffer along with them." (P) (Q)
- "We will reduce risk *and* cost by pushing all risk to our suppliers." [P] [Q]

*All real examples

Using an uncertain demand function improves the decision by revealing a hidden option



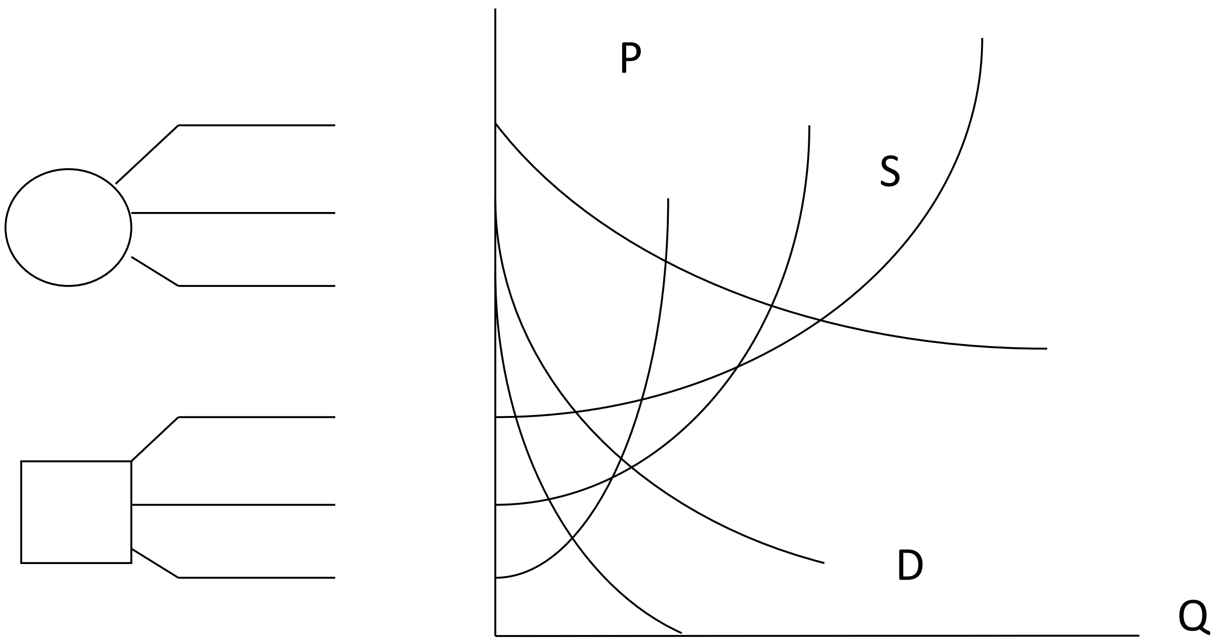
Profit =
quantity(price) * (price - variable cost) - fixed cost

Demand function: quantity = 200 – k2*price,
k2 = 150 (high demand), 175 or 200

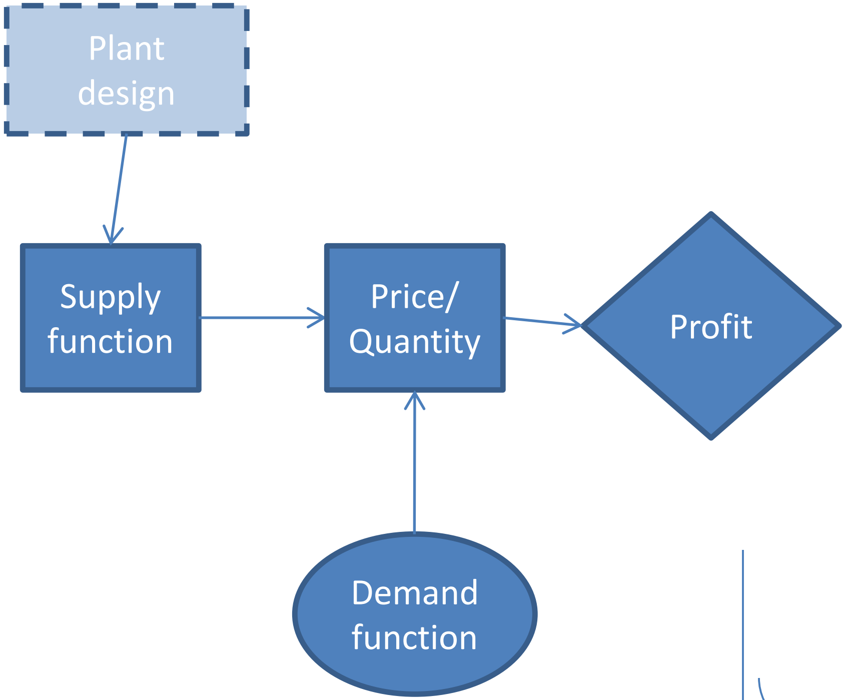
Profit (optimal price)	Small plant	Medium plant	Large plant
Low demand	$225,000 (100)	$175,000 (100)	$50,000 (100)
Medium demand	$475,000 (125)	$425,000 (100 or 125)	$400,000 (100)
High demand	$750,000 (125)	$800,000 (125)	$775,000 (125)
EV	**$483,333**	$466,667	$408,333

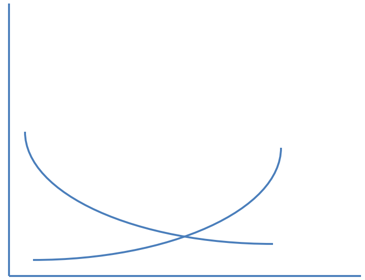
Similar to Cobb, 2011, Graphical Models for Economic Profit Maximization

Economic derivation of price, quantity and resulting surplus for all scenarios

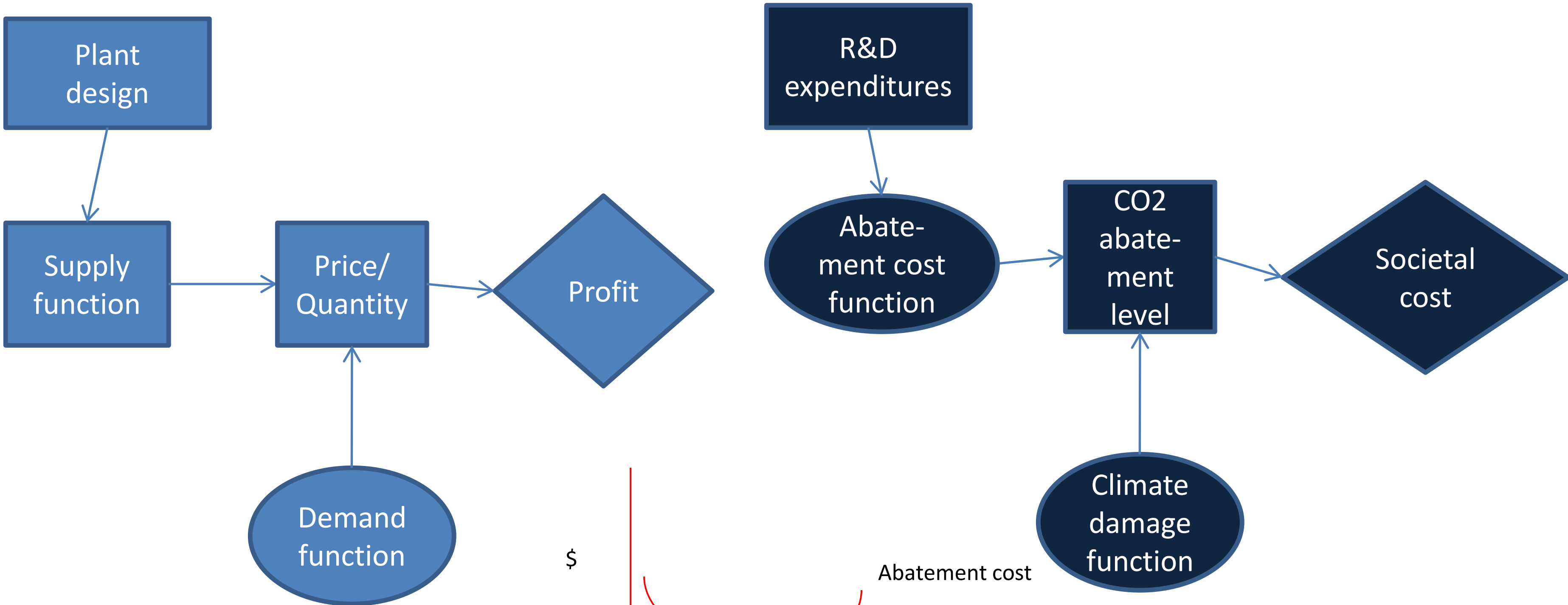


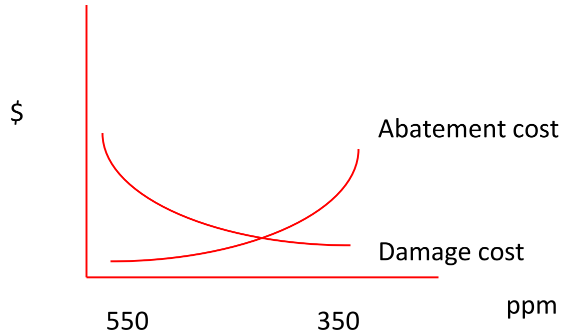
An influence diagram represents this problem with nodes for supply & demand functions





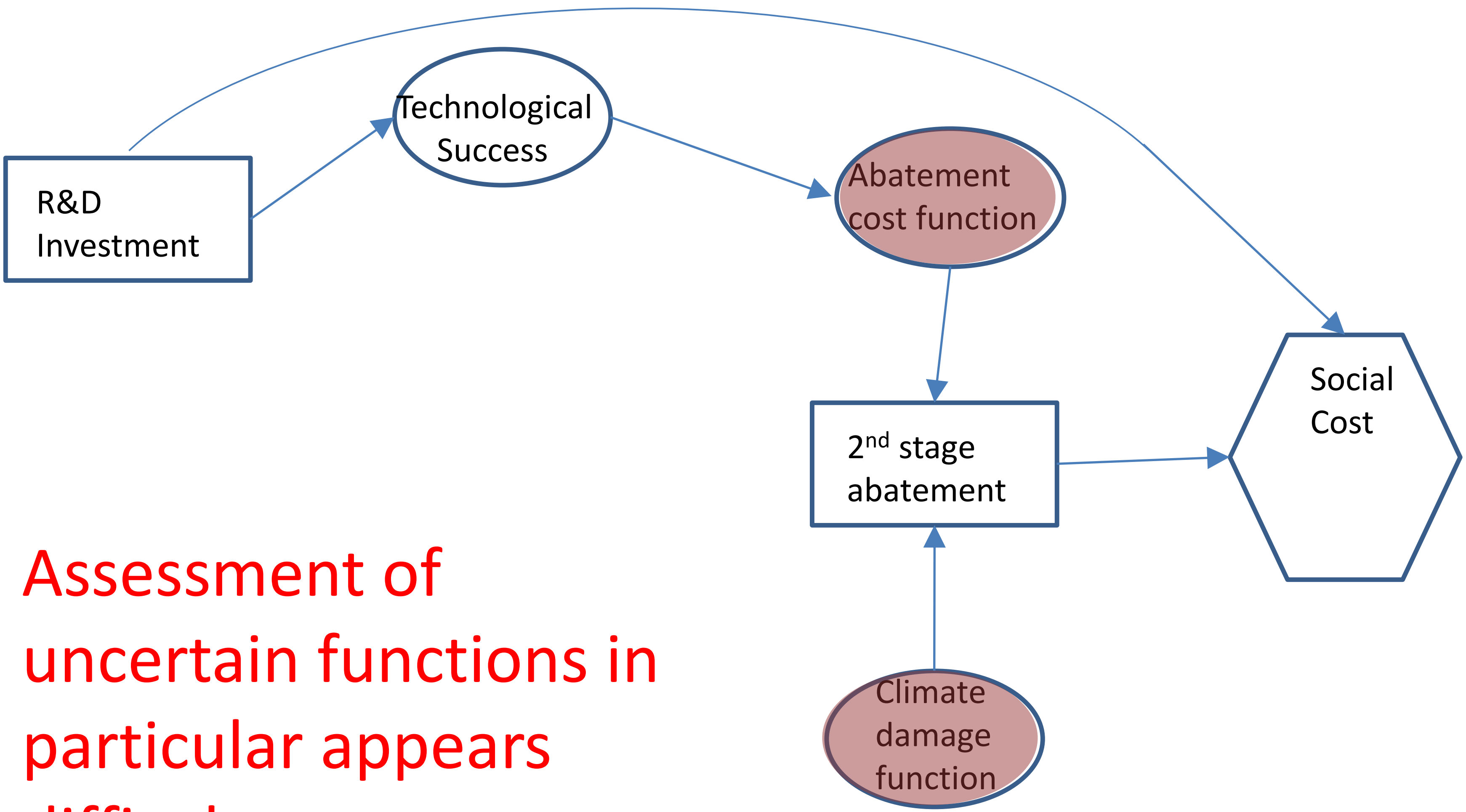
This is similar to a problem in the economics of climate change





*work with Erin Baker

Application to climate change problem

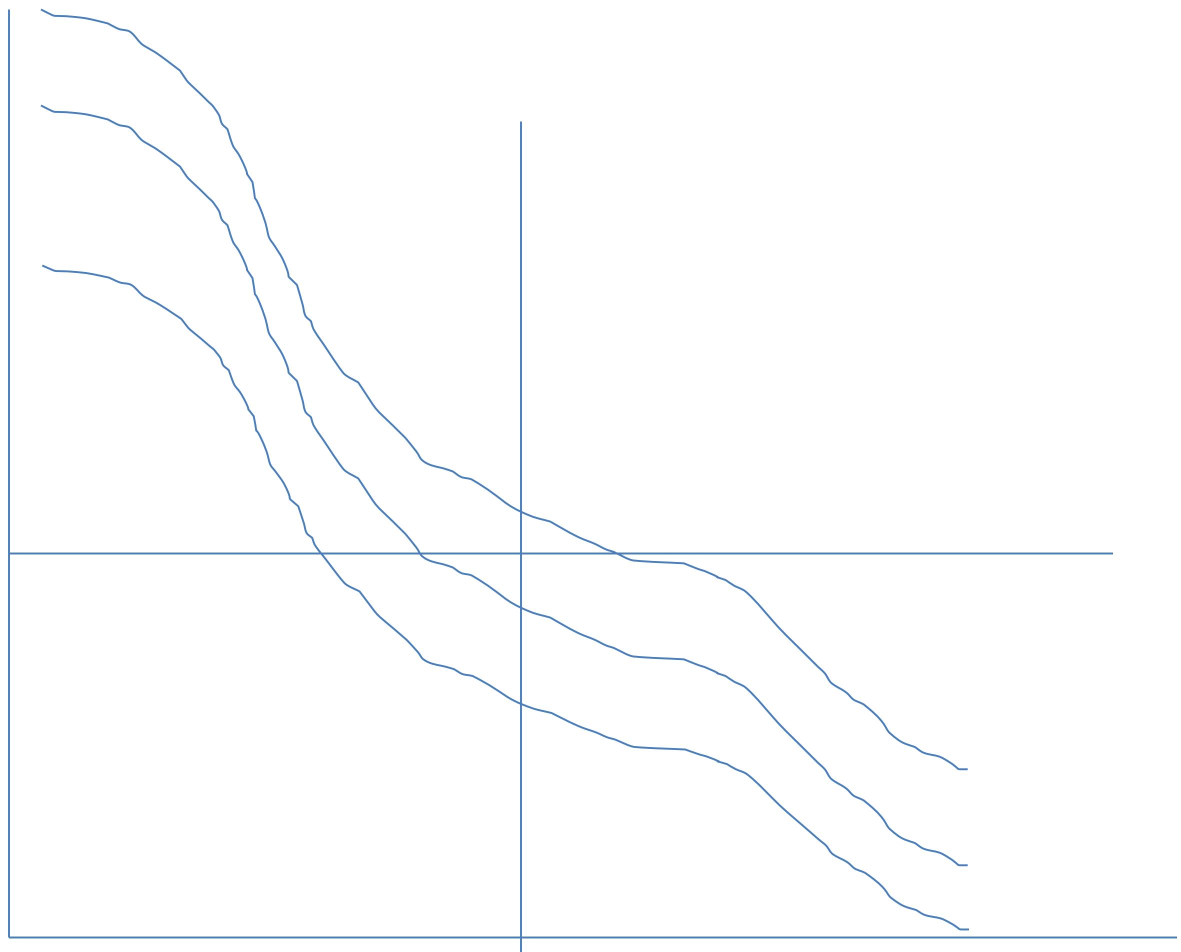


Assessment of uncertain functions in particular appears difficult

Variables that are elements of function spaces naturally extend standard DA

- C: the space continuous functions from R → R
  - Often bounded, e.g., C(0,1): R(0,1) → R(0,1)
- Precedents
  - Random utility functions in BDT choice models
  - Econometrics approaches involving uncertain functions
- DA approach
  - Mathematically consistent with axioms of DA and probability theory
- Need to develop practical methods

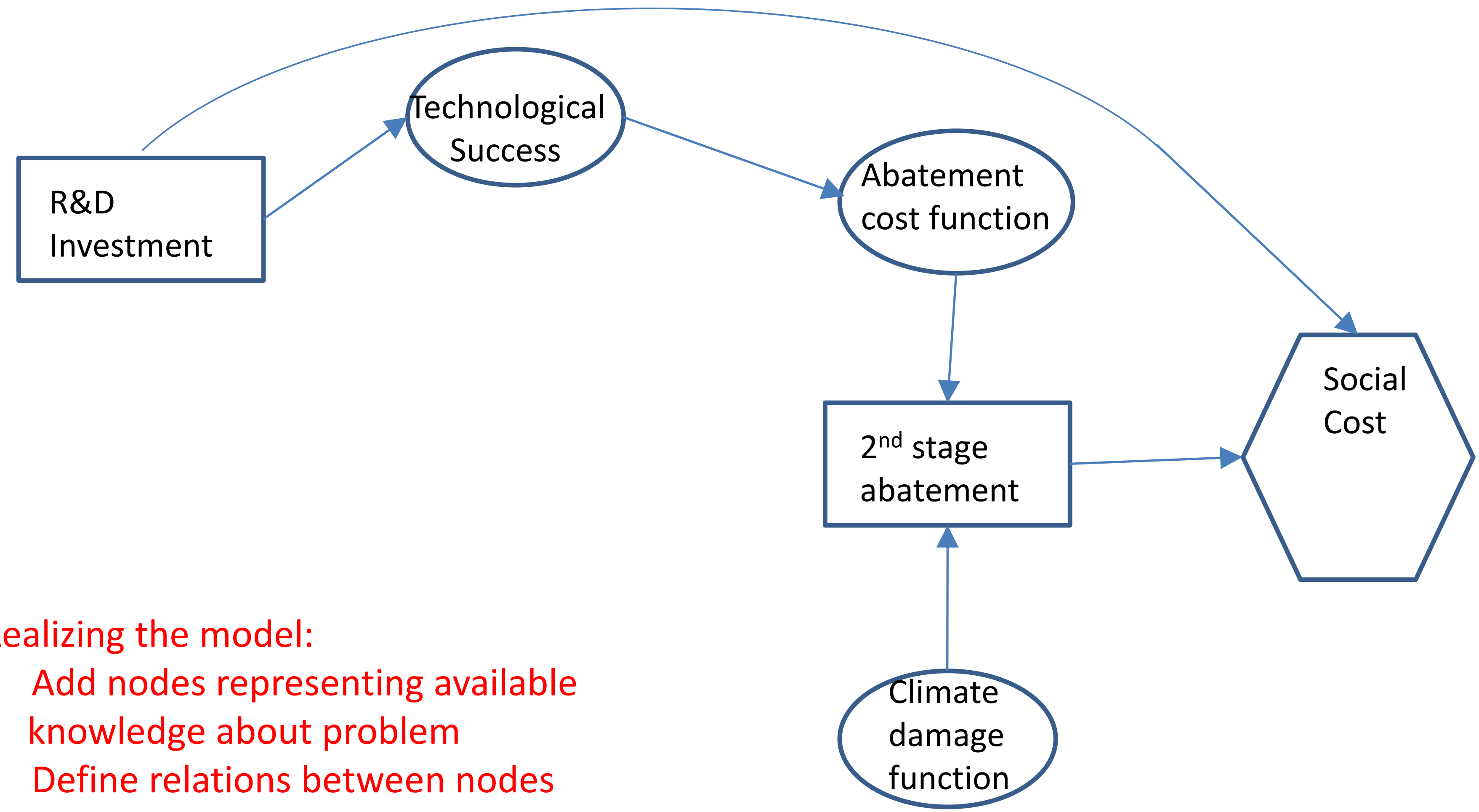
Challenge: Assessing probability measures on space of functions



Assessment methods analogous to those for real-valued variables

- With real variables
  - estimate probabilities of discrete outcomes
  - assumptions about the shape of distribution
- With functions
  - characterize in terms of real parameters
  - assumptions about shape of function
- Choose structure that avoids most difficult elicitations

Application to climate change problem



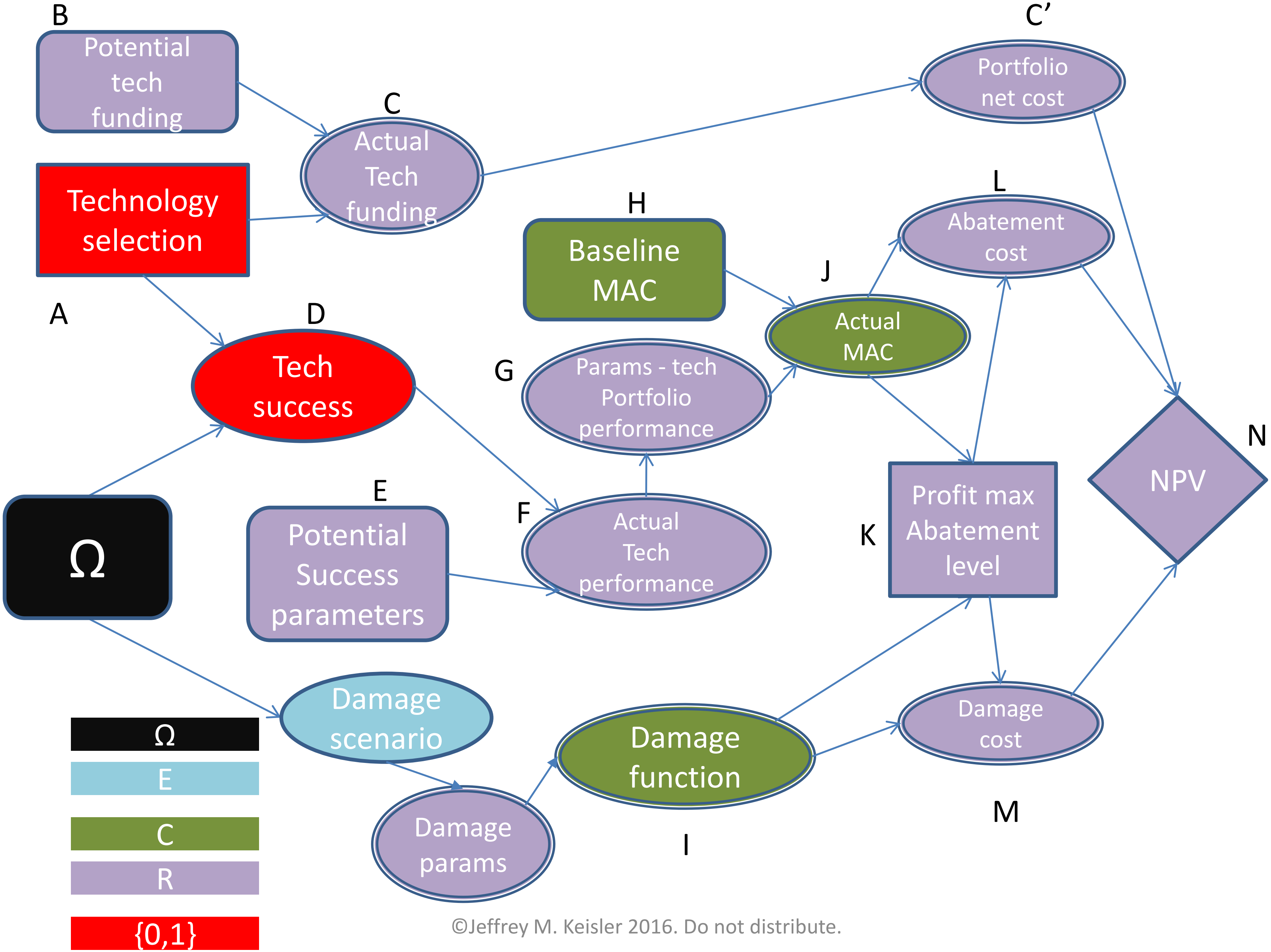
Realizing the model:
- Add nodes representing available knowledge about problem
- Define relations between nodes

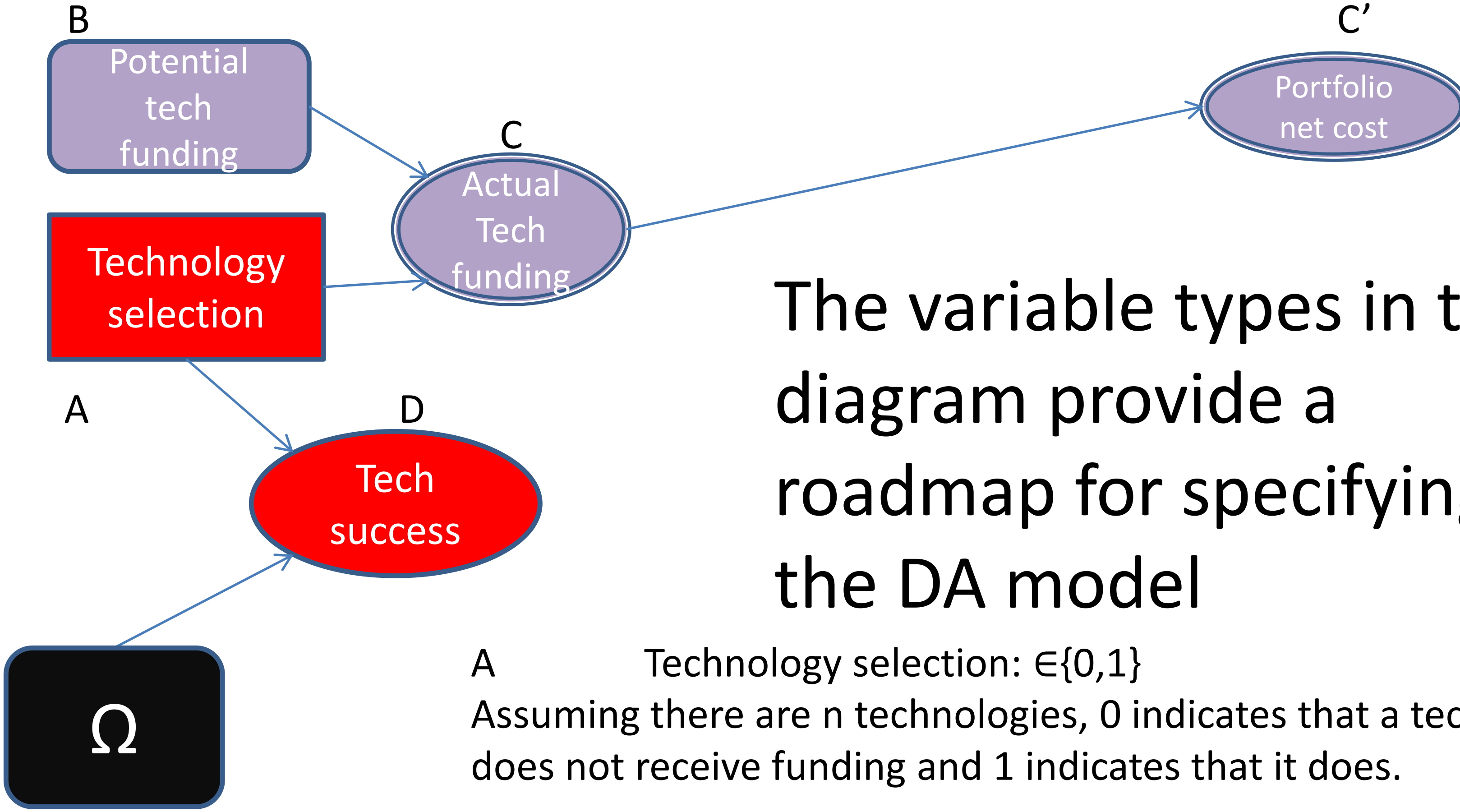
The art of modeling

- Structure so as to model what is hard to assess:
  - Uncertain demand and supply functions
  - Uncertain variables conditional on supply and demand functions
  - Transformations of uncertain supply and demand functions
  - Impacts on supply and demand functions
- Structure so as to assess what is hard to model
  - Likelihood of success
  - Future states

Modeling with malice aforethought

- Composing functions – simplifying by directly modeling or assessing a relationship in a single step
- Decomposing functions – simplify by breaking complicated variables into parts where it is clearer how to assess or construct connections
- Ordering nodes – Can rearrange
  - Bayes' rule holds for function-valued variables
- Leads to a workable influence diagram, e.g., as follows


B
Potential tech funding
C
Actual Tech funding
C'
Portfolio net cost
Technology selection
A
H
Baseline MAC
L
Abatement cost
J
Actual MAC
D
Tech success
G
Params - tech Portfolio performance
N
NPV
E
F
Actual Tech performance
K
Profit max Abatement level
Ω
Potential Success parameters
Damage scenario
Damage cost
Damage function
Damage params
M
I
Ω
E
C
R
{0,1}

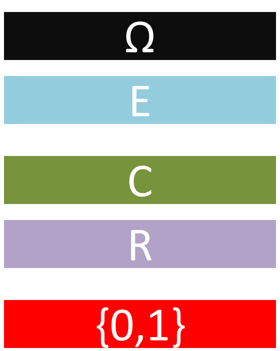


The variable types in the diagram provide a roadmap for specifying the DA model

A Technology selection: ∈{0,1}
Assuming there are n technologies, 0 indicates that a technology does not receive funding and 1 indicates that it does.

B Potential Funding for technologies: ∈ R^n.
For each technology, we defined a funding trajectory to be assumed for later judgments; the NPV of a funded project is a social cost.

C Actual funding portfolio $\{0,1\}^n \times R^n \rightarrow R^n$
Simply multiplies A and B.
C’ Total NPV of funding for the portfolio (simply sums values from C)



Chance nodes represent mappings; elicit probability functions

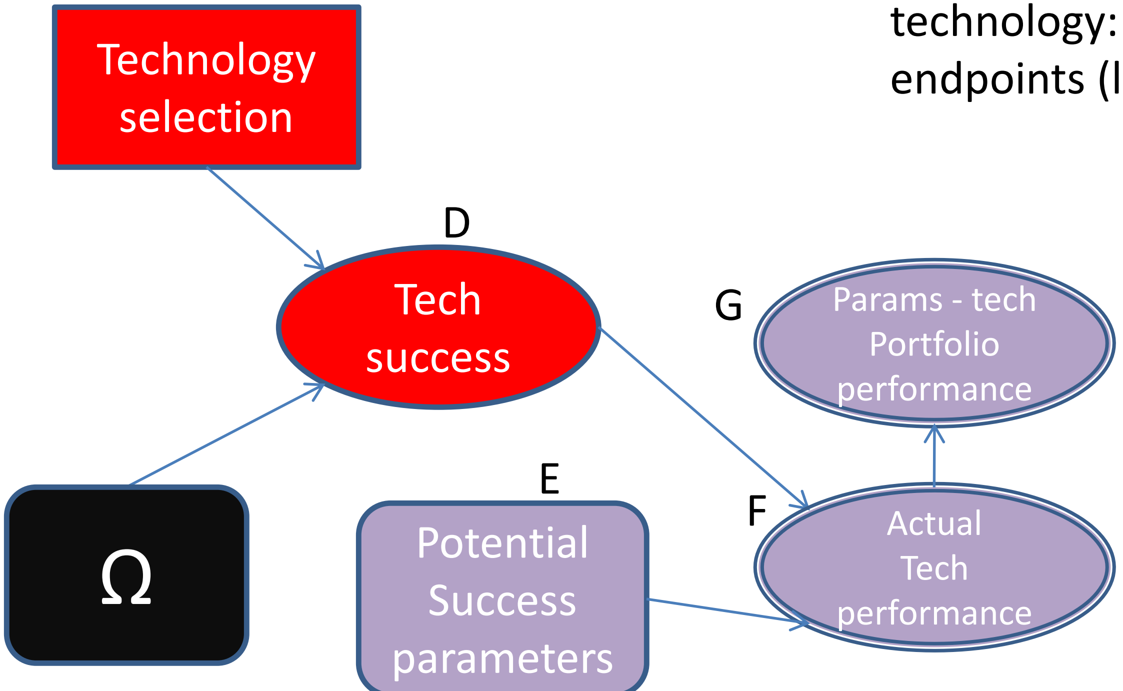
- $\Omega \rightarrow \{0,1\}$, $\Omega \rightarrow E$, $\Omega \rightarrow R$: standard DA assessments
- $\Omega \times E \rightarrow E$, $\Omega \times R \rightarrow E$ etc.: Standard conditional assessments
- $\Omega \rightarrow C$: Exotic assessment methods
- $\Omega \times E \rightarrow C$: Exotic conditional assessments (difficult)

Deterministic nodes and relationships are modeled with standard math

- *E* → *E* or *E* → *R* or *R* → *E, R* → *R*
  - Simple spreadsheet functions, operations, formulas

COMMON IN ECONOMIC ANALYSIS

- *C* → *R*
  - Functionals, e.g., Short programs, such as integration
- *R* → *C*
  - Creating parametric functions, Spreadsheet formulas
- *C* → *C*
  - Operators, e.g., specialized programs

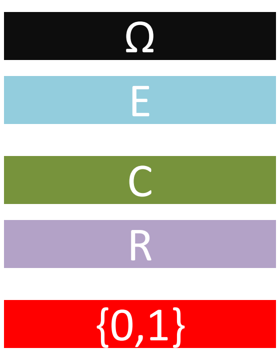


D Technology success: $\{0,1\}^n \times \Omega \rightarrow \{0,1\}^n$
Standard R&D portfolio probability assessments

E Potential Success parameters for a technology: R^{m*n} using carefully defined endpoints (looking ahead)

F Actual successful technology performance: $\{0,1\}^n \times R^{m*n} \rightarrow R^{m*n}$ Simply multiplies D and E

G Technology portfolio performance: $R^{m*n} \rightarrow R^m$ Combines impact of all successful projects (F), as additive parameters to be used to calculate vertical shift, horizontal shift, etc. of the MAC

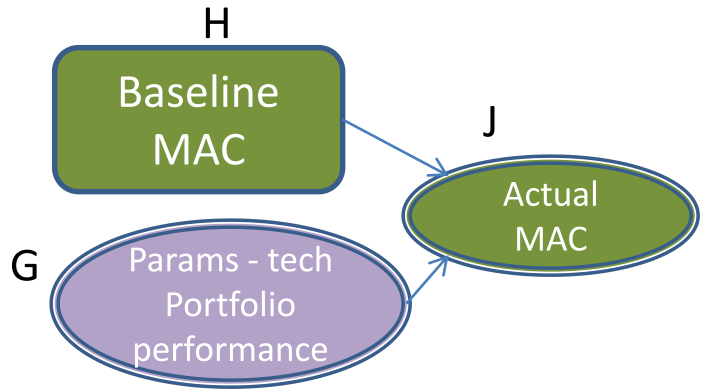


H Baseline abatement curve: $\in C$

We used the curve for the standard scenario already developed for Minicam.

J Actual abatement cost function: $C \times R^n \rightarrow C$

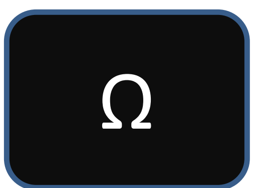
Uses various **linear operators** applied to the function in H and the parameter values from G.

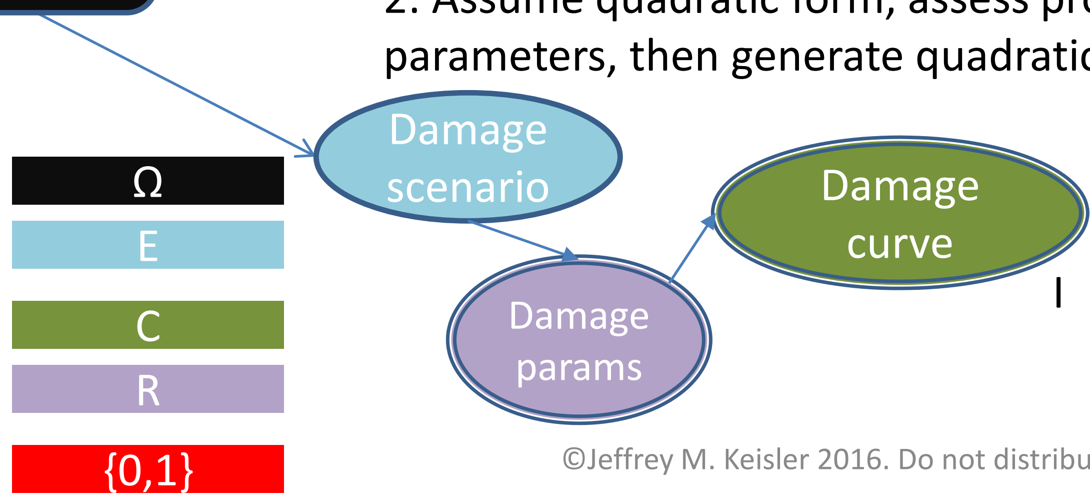


I Damage curve: $\Omega \rightarrow C$ *(derived from literature)*

1: Discrete set of scenarios, 1 curve per scenario, assess probability function $\Omega \rightarrow E$, and then define curve for each event $E \rightarrow C$.

2: Assume quadratic form, assess probability function $\Omega \rightarrow R^3$ on parameters, then generate quadratic function $R^3 \rightarrow C$.



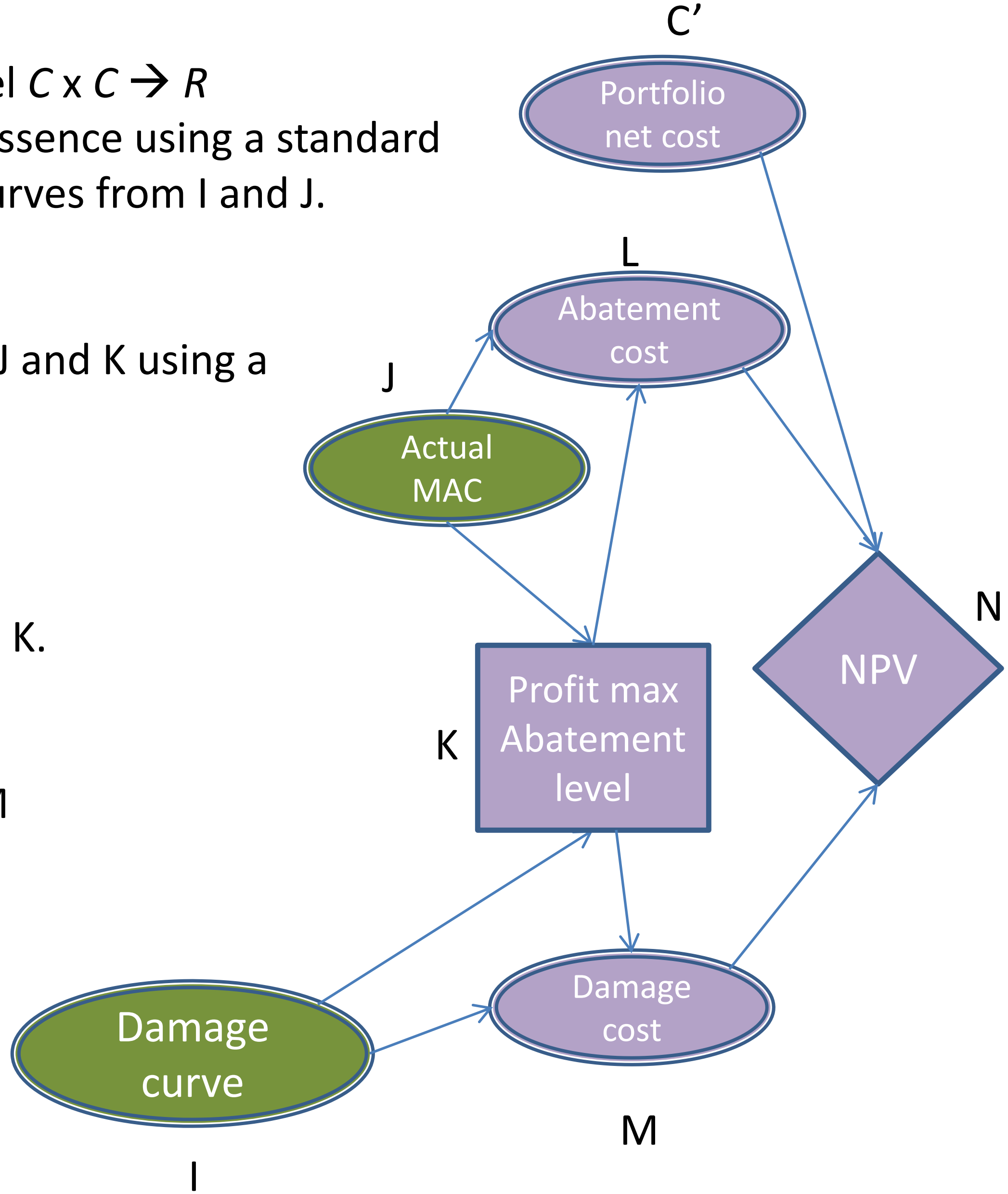


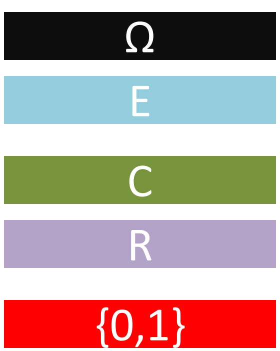
K Profit maximizing abatement level $C \times C \rightarrow R$
This is implemented in Minicam, in essence using a standard economic **functional** based on the curves from I and J.

L Abatement cost $R \times C \rightarrow R$
This is calculated from the results of J and K using a simple economic **functional** – reading a value off the curve.

M Damage cost $R \times C \rightarrow R$
Similar to L, using the results of I and K.

N Societal cost: $R^3 \rightarrow R$
Simply adds the results of C', L and M (with appropriate discounting)





The composition of these functions is used to calculate expected societal cost for any given R&D portfolio

- N(C'(A,B),L(J(H,G(F(D(A,Ω),E))),K(I(Ω),J(H,G(F(D(A,Ω),E))))), M(I(Ω),K(I(Ω),J(H,G(F)))

- We'll let the computer handle that one!
- Simpler to compute but impossible to assess would be E[N(A, Ω)] for each alternative

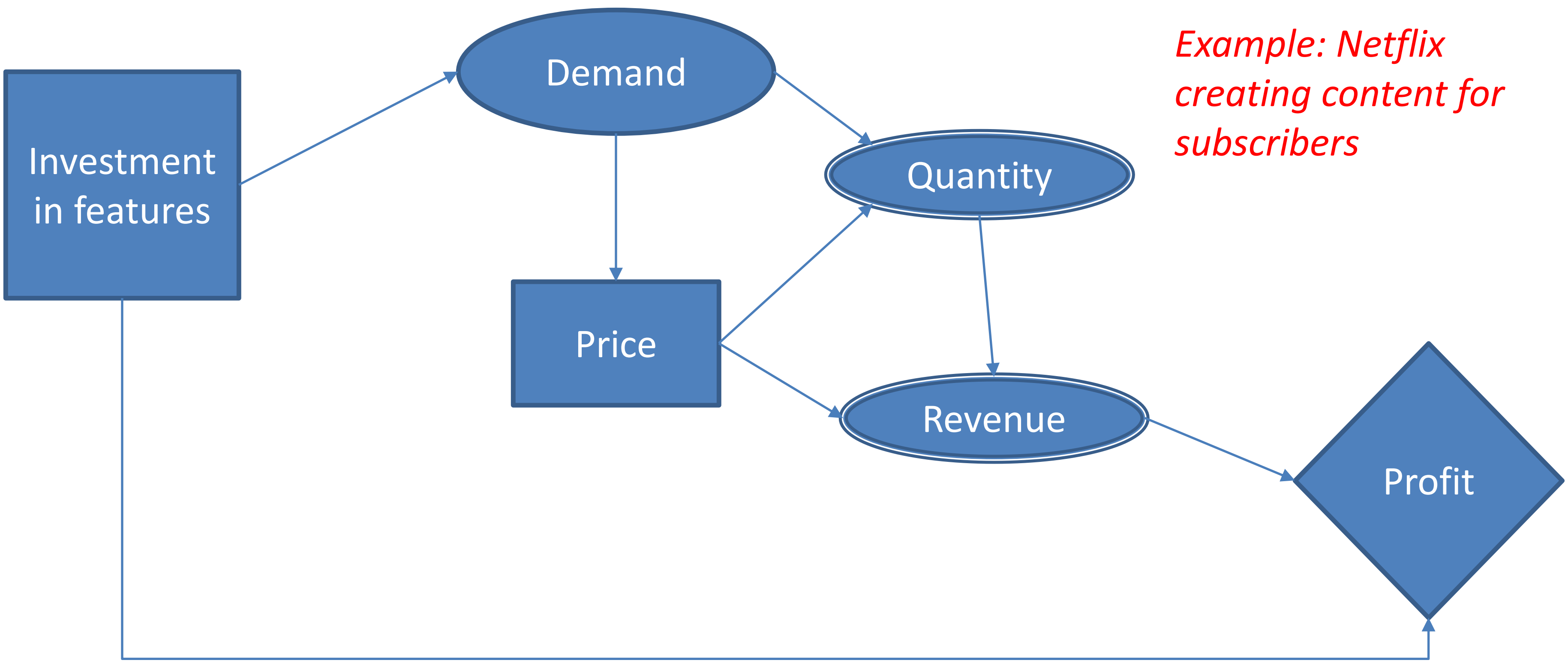
Implementation

- Structured assessments according to the plan to anticipate connection to economic analysis models
  - Identified technical hurdles
  - Assessed probability of success as function of funding
  - Endpoints of R&D success were individual technology parameters (e.g., cost/Kg) that could be combined into economy-wide parameters used to derive economy wide abatement cost curve, or allow direct calculation of amount of “shift”, “pivot” of functions, etc.
  - Defined and estimated functional relationships
- Range of possible damage curves from published literature
  - Based on scientific climate models and economic models
- Modeling in Minicam/DICE (Baker & Solak) produced suggestive results

Platform ecosystems
(if we have more time)

- Two sided markets
  - Value to buyers depends on number of sellers
  - Value to sellers depends on number of buyers
  - Extends to multi-sided markets
- Economic / strategy theory since ~2000
- Current efforts
  - specifying decision analytic approach
  - starting simple

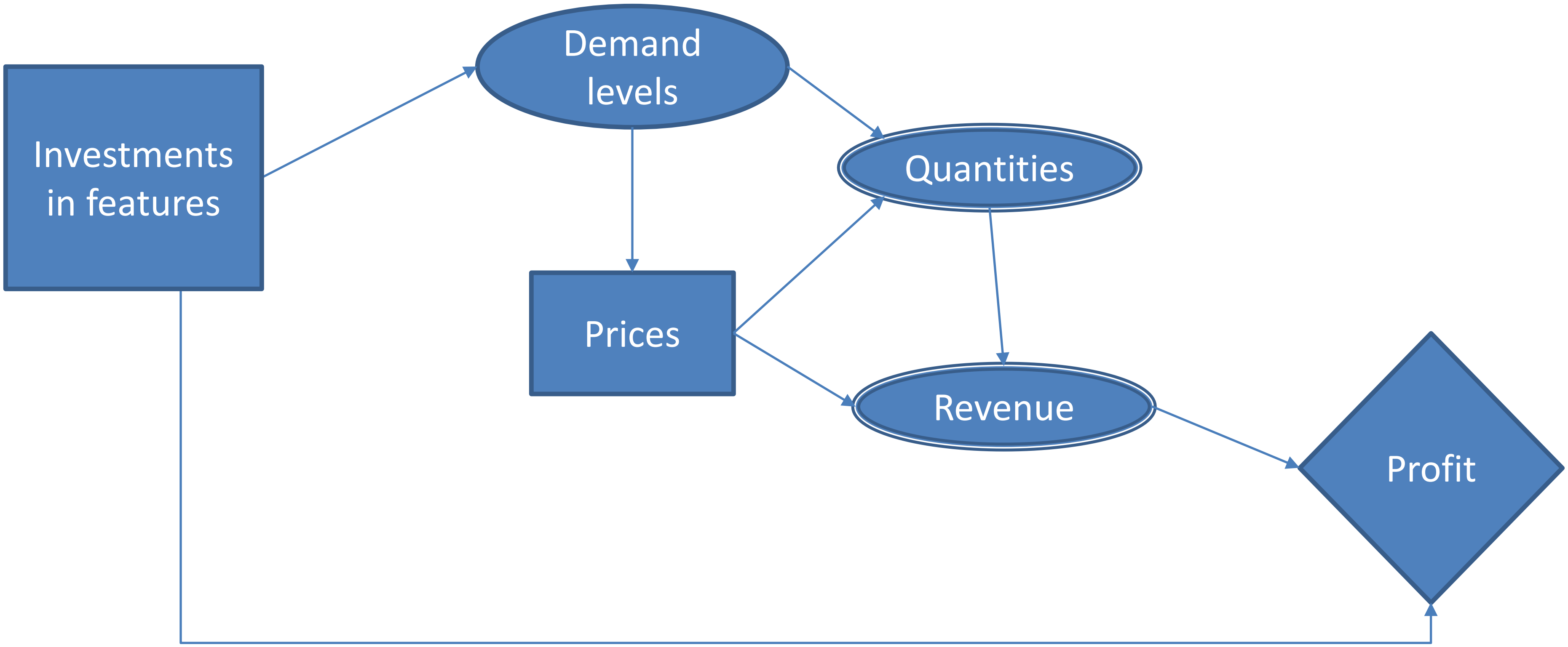
One-sided market platform model is variation on earlier examples



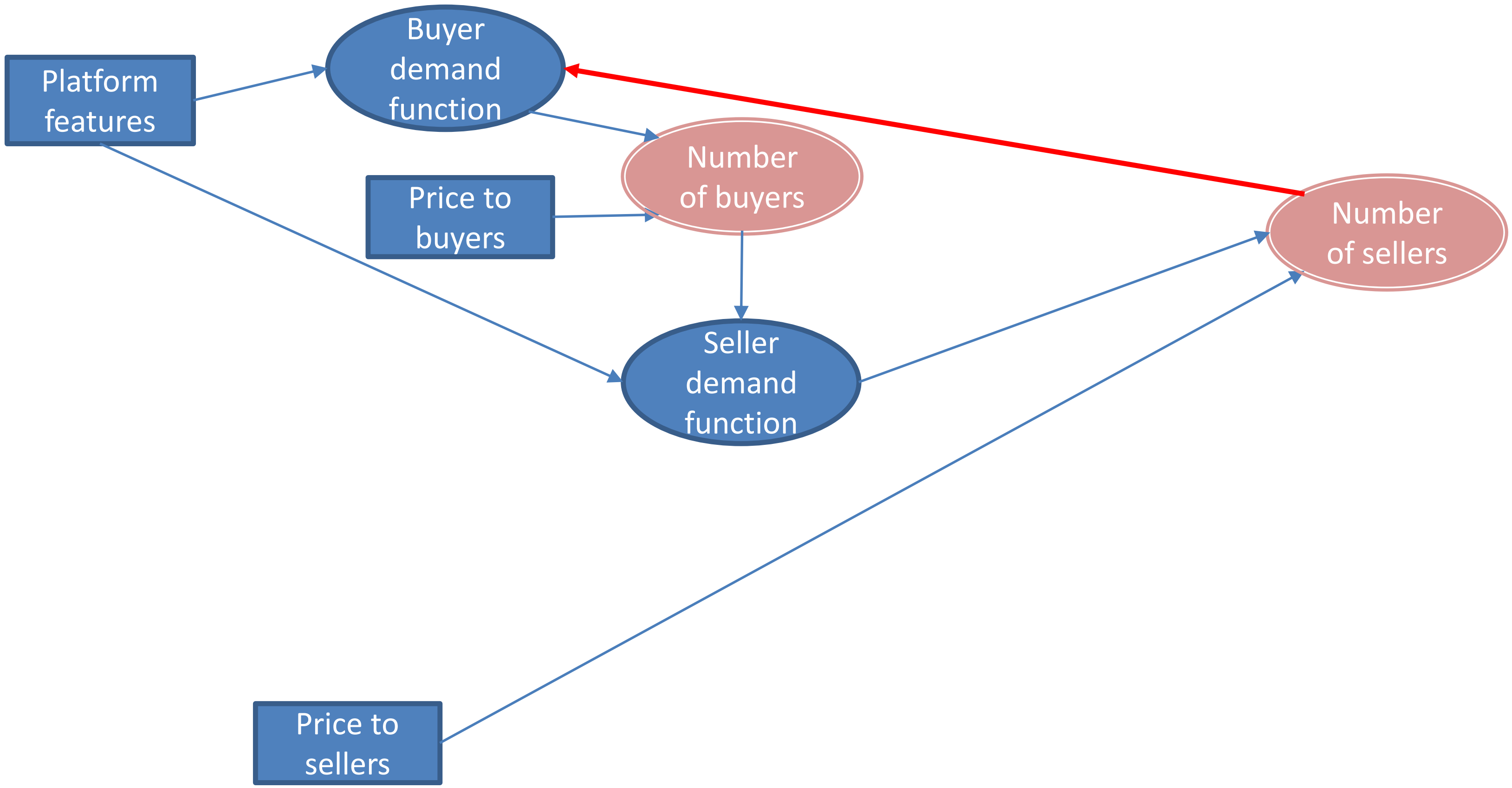
Example: Netflix creating content for subscribers

Assume quantity represents number of users, price is fee per user, with no additional modeling of individual transactions

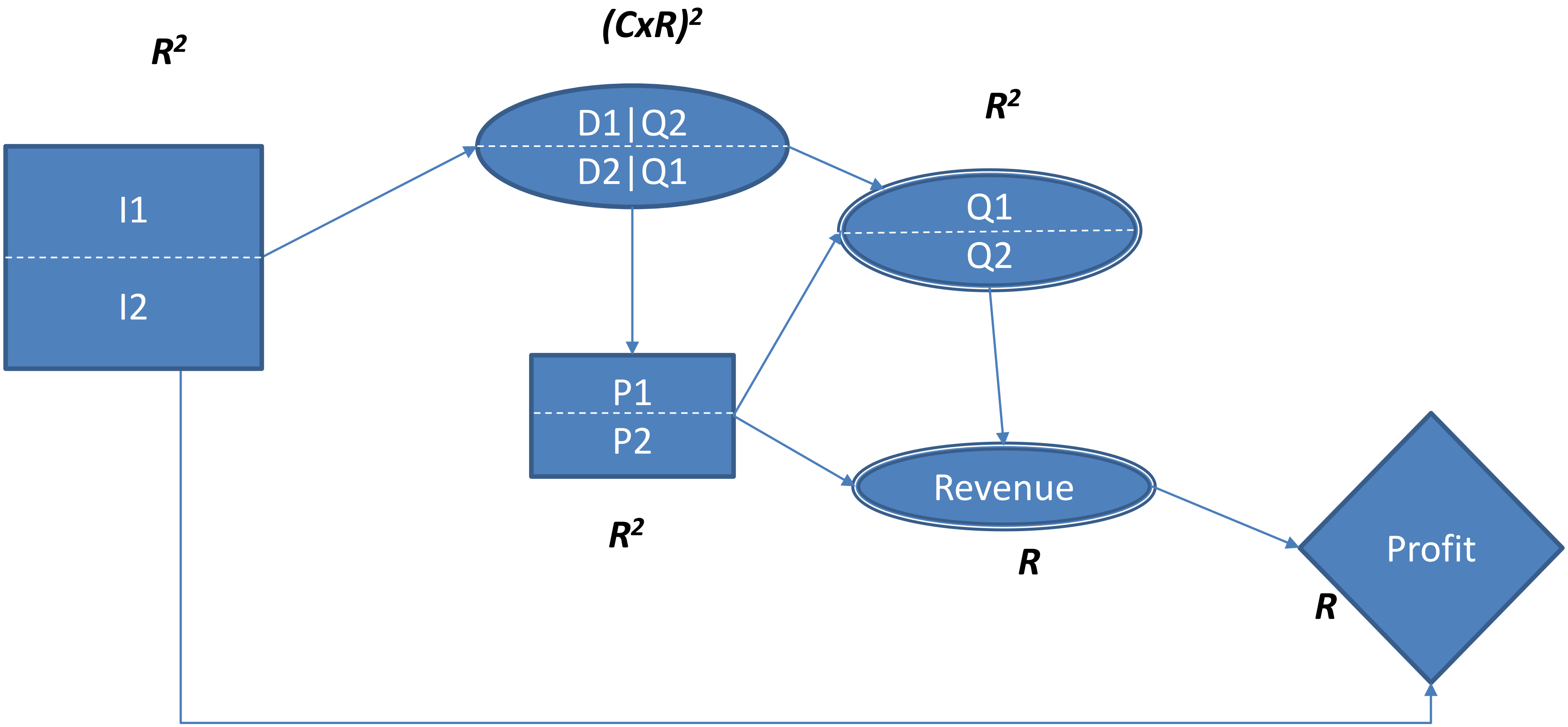
Two sided market – Same diagram but more complicated implementation



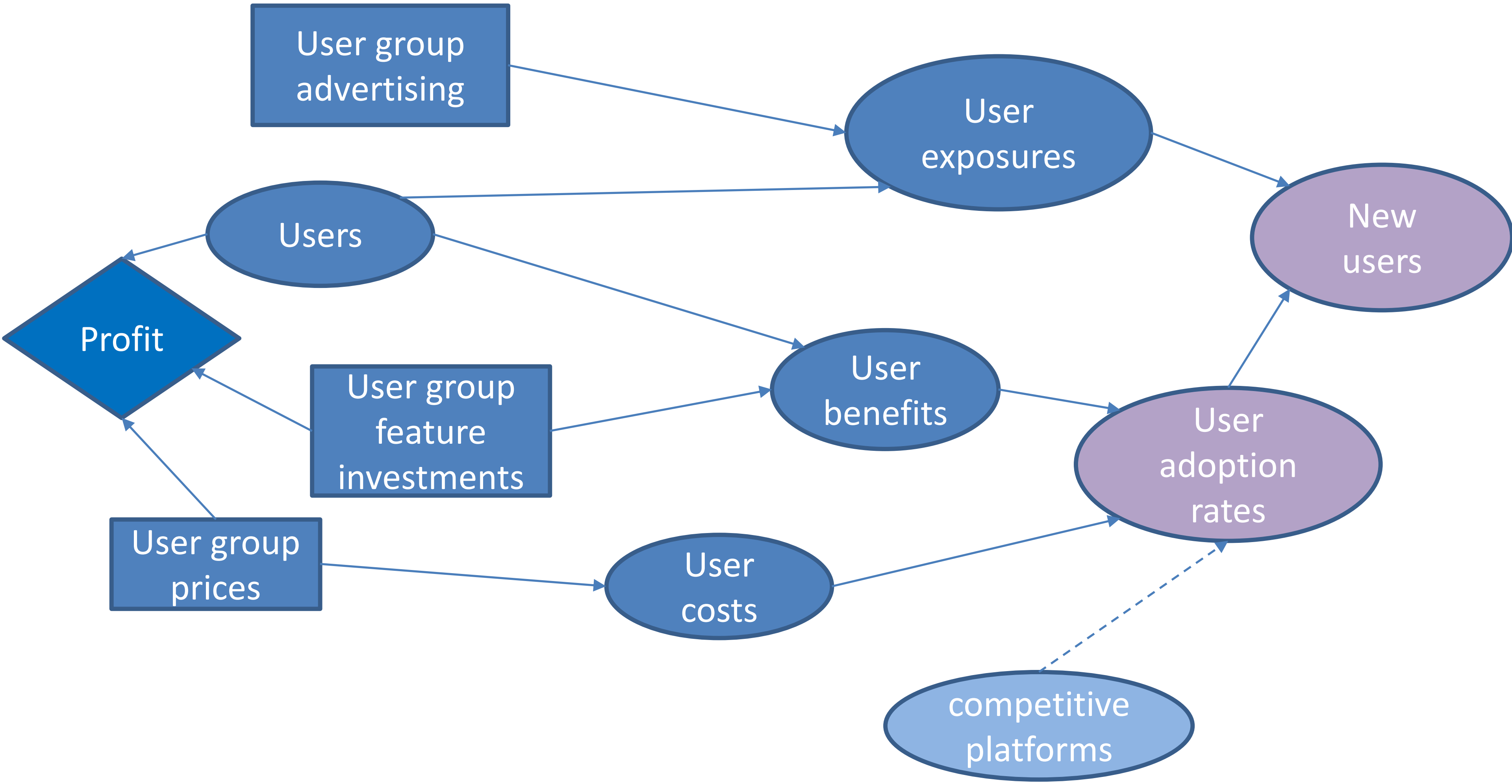
Influence diagrams do NOT have cycles



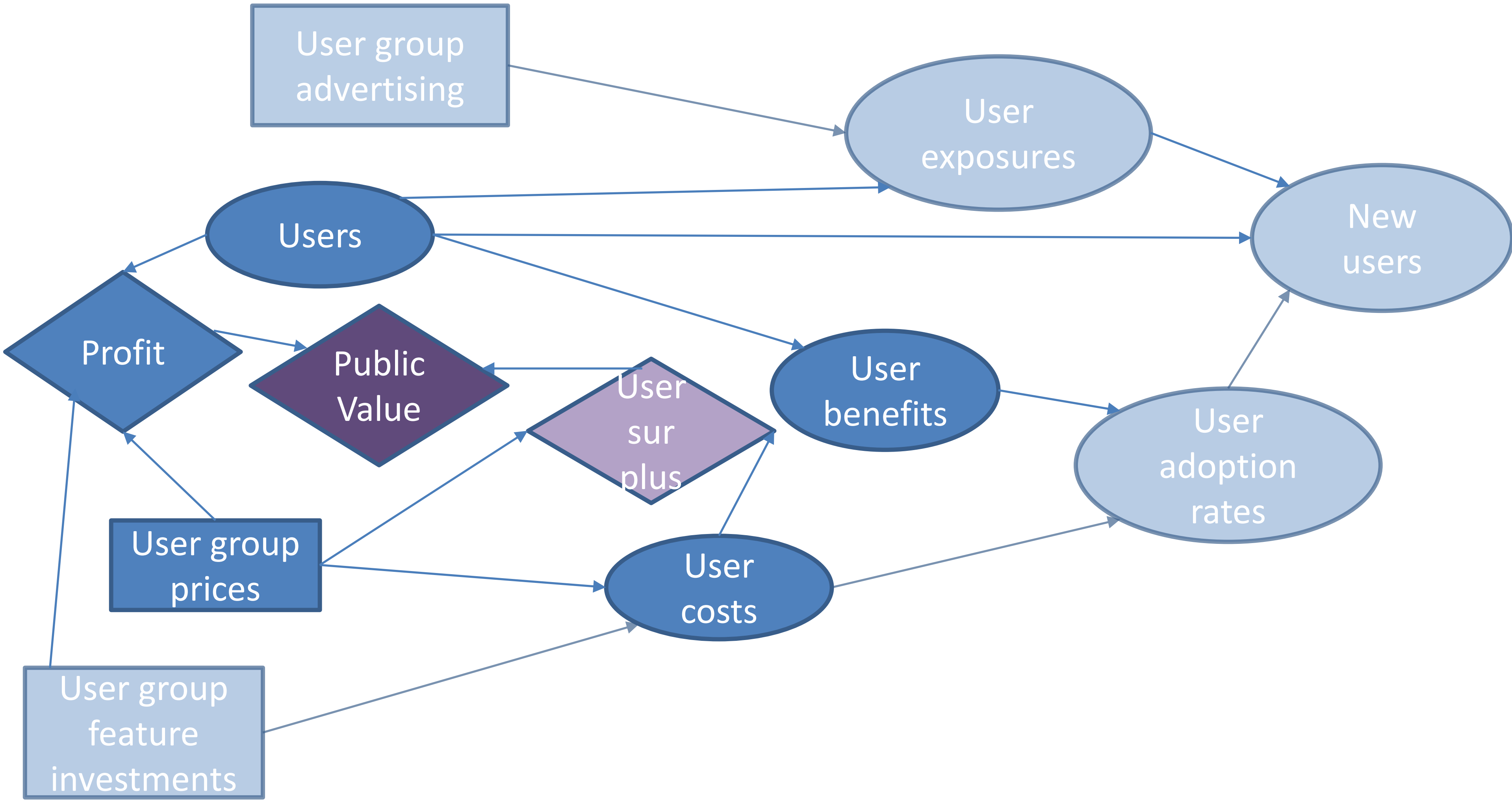
Solution



Dynamic model



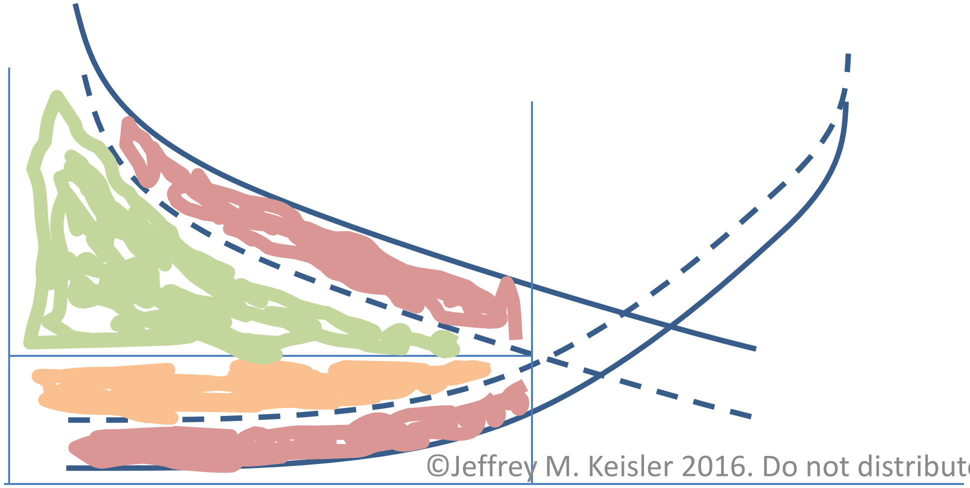
Public perspective

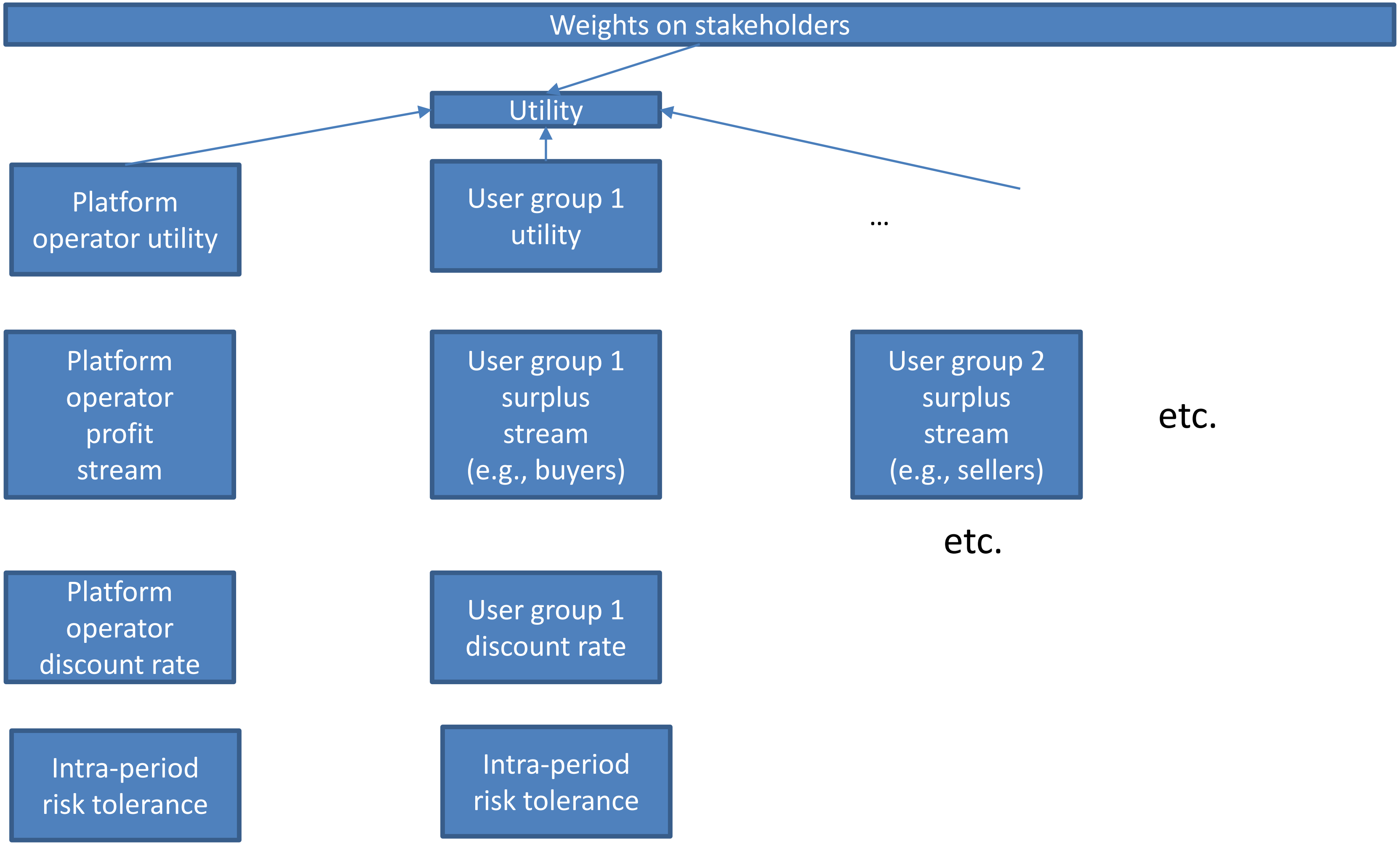


Spreadsheet example

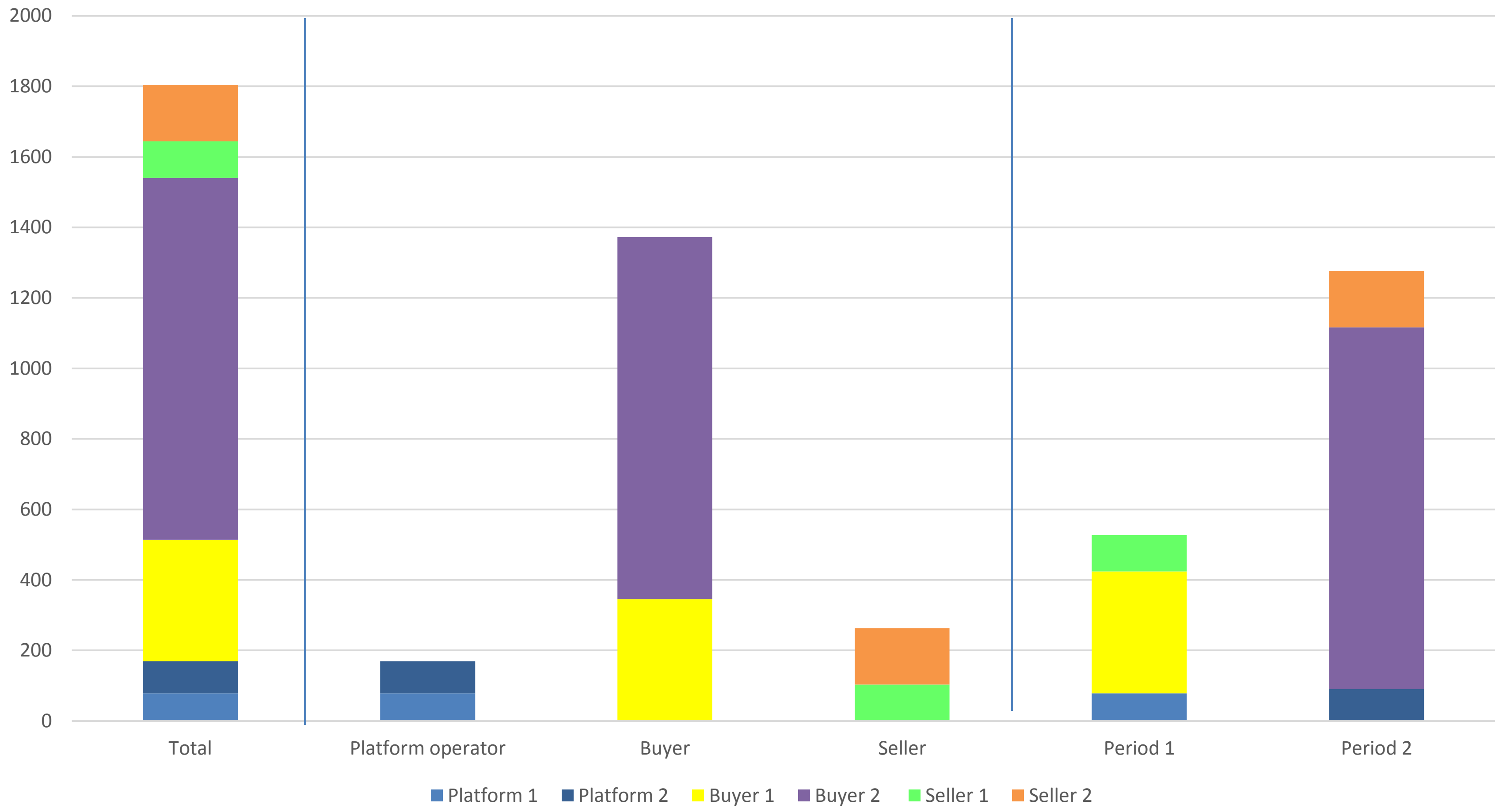
Extension to government problem

- Balancing interests in backing plans
- Economic analysis computes buyer surplus, seller surplus, platform operator profit, etc.
- Discount over time
- Can use MCDA / MAU for multi-stakeholder view




Weights on stakeholders
Utility
Platform operator utility
User group 1 utility
…
Platform operator profit stream
User group 1 surplus stream (e.g., buyers)
User group 2 surplus stream (e.g., sellers)
etc.
etc.
Platform operator discount rate
User group 1 discount rate
Intra-period risk tolerance
Intra-period risk tolerance

Breakdown of platform benefits



Conclusion

- Decision analysis can use function valued variables
- Structuring models requires some novel ways
- Allowing incorporation of common micro-economic modeling methods
- Enabling insights about complicated problems like platform ecosystem design

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