Building (and estimating) Economic Models

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Building A Theoretical Model: First define research question

- Essential to place the paper in the literature.
- We examine… It differs from the previous literature because…By analyzing this setting, we learn…
- Important not to reinvent the wheel. Some "security economics" settings are simply special cases of well established economics models.

(adverse selection, moral hazard, externalities, etc.)

Then Build A Simple Model

- Remember that a model is meant to be an abstraction, within which we wish to draw robust conclusions
- Models are especially useful in analyzing trade offs.
- Look for the essential trade offs involved in your problem and build the simplest structure possible to examine the tradeoffs
- Use the basic model as a benchmark: Expand it by successively abandoning restrictive assumptions. (It's easier to expand than simplify)

What we included in our model

- α -- Probability firm will find the problems before hackers.
- γ -- Probability of attack if no disclosure.
- θ -- consumer heterogeneity (Value of software, Damage from attack)
- n--Number of security vulnerabilities
- c – cost to consumers of downloading & installing updates

Effects We Did Not Include in Model

I. Negative Network Effect
II. Investment to reduce "n"
III. Endogenize "α"

- (I) Negative network effect (NNE) makes our model "sexy," but model cannot be analytically solved. NNE not needed to answer research question
- (II) and (III) We keep n and α exogenous, and then address how changes in them affect disclosure policy

Endogenous vs. Exogenous Variables

- Key decision: which variables should be exogenous and which variables should be determined endogenously.
- Look for the variables involved in the principle tradeoffs, and keep all others exogenous.
- First model an individual decision-making situation. Use this as a benchmark. Then add strategic interaction if appropriate.

Choose Realistic Policies for Regulator

- In our model…
- (I) Set Price?

Unrealistic

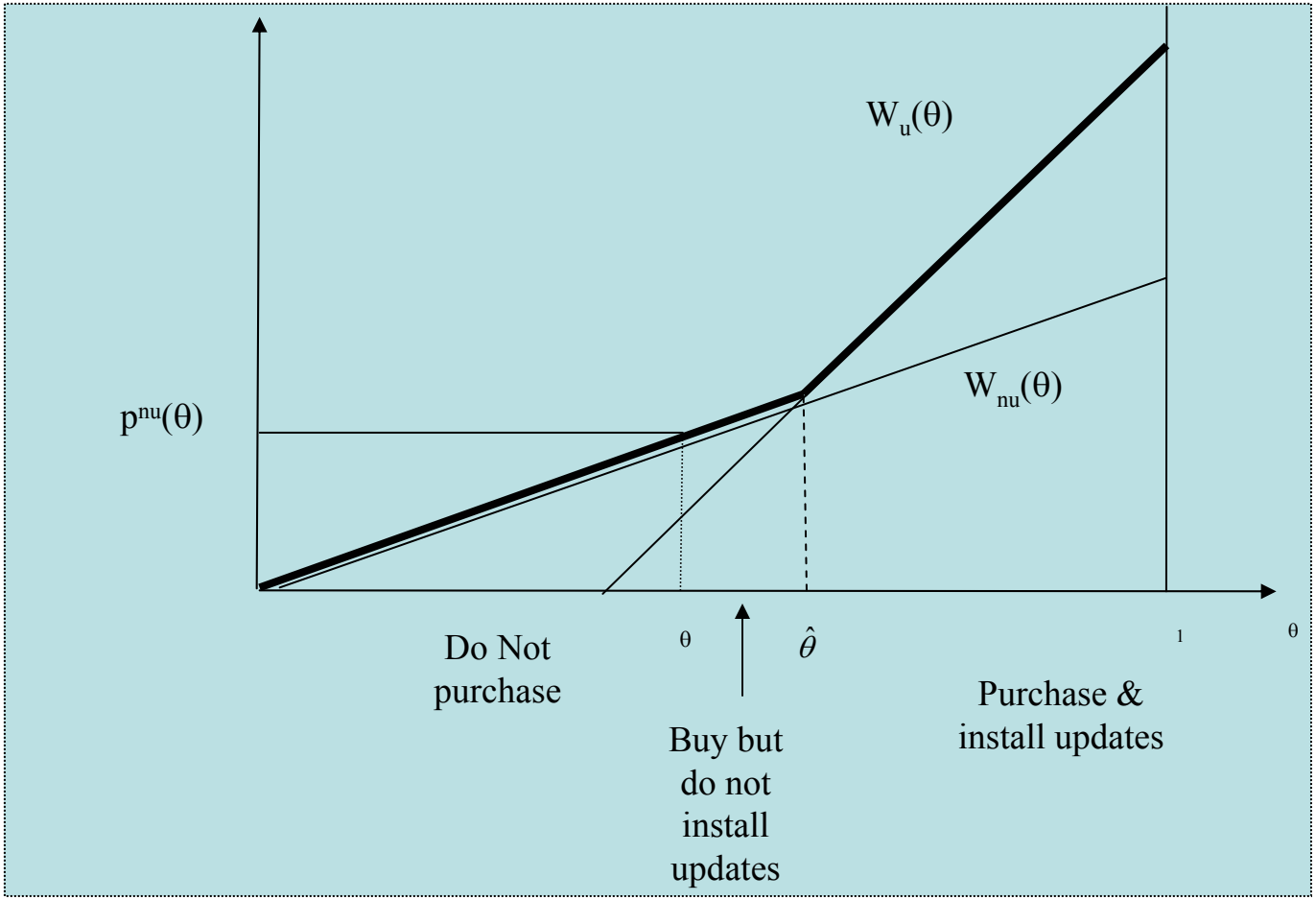
- (II) Require Consumers to Install Updates?

Unrealistic

- (III) Set Disclosure Policy?

Realistic -- CERT/CC policy effectively mandates disclosure of vulnerabilities it reports to firms

Use Figures to Clarify



Interpreting Welfare Results

- Total Surplus vs. Consumer Surplus
- Social optimum typically differs from market outcome. But we should be careful before concluding that intervention is desirable.
- In our setting, there are benefits from mandatory disclosure. But there are costs too. (In one case, there are only costs…)

Key Components a Model

Decision maker(s)

Strategies

Order actions by degree of reversibility.
(Invest in Stage 1; set prices in stage 2)

Payoffs (utility, profits) dependent on all possible actions

Key Modeling Choices

- Homogenous vs. Differentiated Consumers/Goods
- Single Decision Maker vs. Strategic Interaction
- Simultaneous vs. Sequential Timing (Are the results robust to changes in timing?)
- Commitment/Repeated Actions
- Make sure you know which assumptions are driving the results!

Brief Thoughts on Estimating Economics Models
Structural vs. Reduced Form Modeling

Structural economic model - stochastic model of behavior of economic agents.

It gives rise to a reduced form model, which is a conditional distribution of endogenous variables on exogenous variables.

Example of a Structural Model: (Supply & Demand)

$$q_t^s = \alpha_0 + \alpha_1 p_t + \alpha_2 x_{1t} + \varepsilon_{1t}$$

$$q_t^d = \beta_0 + \beta_1 p_t + \beta_2 x_{2t} + \varepsilon_{2t}$$

$$q_t^s = q_t^d \equiv q_t \text{ (equilibrium condition)}$$

p_t , q_t –endogenous variables

x_{1t} , x_{2t} –exogenous variables

ε_{1t} , ε_{2t}-- stochastic shock, α , β parameters

Structural Models

The above is a structural model because:

- The demand function specifies a behavioral response of consumers in the market.
- The supply function specifies a behavioral response of firms in the market.
- We assume that market is in equilibrium.

Why do we employ structural models?

- To estimate parameters or effects not directly observed in the data (returns to scale, elasticity of demand)
- to perform welfare analysis, i.e., measure welfare gains due to entry, or welfare losses due to market power.
- To simulate changes in the equilibrium (counterfactuals --- simulate impact of mergers)
- To compare relative predictive performance of competing theories

Reduced Form

The simultaneous solution of supply and demand functions yields functions with the endogenous variables on the left hand side and the exogenous variables on the right hand side.

Reduced Form:

$$q_t = a_0 + a_1 x_{1t} + a_2 x_{2t} + f(\varepsilon_{1t}, \varepsilon_{2t})$$

$$p_t = b_0 + b_1 x_{1t} + b_2 x_{2t} + g(\varepsilon_{1t}, \varepsilon_{2t})$$

Data can only tell us something about the reduced form parameters (**a**,**b**).

Identification (of the structural model) occurs if there exists a unique set of structural parameters (α, β) associated with a given set of reduced form parameters (**a**,**b**).

Identification relies on exclusion restrictions and functional form. Hopefully, identification will come (in part) from economic theory.

Additional Thoughts

Structure Model enables us to separate correlation from causality!

Is a structural model the only way to answer all interesting economic questions? NO!

- With the reduced form, we can learn the conditional distribution of the endogenous variables, given the exogenous variables (i.e., predictions about the impact of changes in income on demand.)
- We can learn about the raw correlations in the data (but we must be careful not to give this a structural interpretation).
- We can test among between different theories if they give different predictions about reduced form.

Structural Model vs. Reduced Form

With a structural model, we get more information, but at the potential cost of less robust results

With a reduced form model, we get less information, but results are typically more robust.

There are ways to combine the best of both worlds:

- Perform the analysis gradually, i.e., start from the reduced form and add structure to learn more

Principles to Keep in mind when conducting empirical work

- Have a clear research question
- Use economic theory
- Come up with an ideal experiment
- Get data (usually the limiting factor)
- Be sure that you know what experiment you're conducting