Two-Sided Markets, Pricing, and Network Effects

Part II: Identification of Network Effects

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Outline

Direct v.s. Indirect Network Effects

Definition

- **Direct network effects:** The value of a product depends on other consumers purchasing or using the same product.
- **Indirect network effects:** The value depends on the provision of some com plementary good and that provision depends on other consumers purchasing or using the product.

- Why begin with direct network effects?
  - Only one product. ⇒ Provides a easier context for identification.
  - Lack of data. ⇒ Model indirect as direct network effects.
  - More comparable to other fields of economics.

Base Model: Setup

- A partition of agents into markets $m = 1, ..., M$. Each market has one network and agents choose how much to use the network in their market (a).
- Network effects operate only within a market.
- Each agent makes a continuous choice $a \in R$ that incurs a constant marginal price of P_m.
- The optimal choice for each agent:

$$a = \beta_0 - \beta_1 P_m + \beta_2 q_m + \zeta_m + \varepsilon$$

- $q_m = \bar{a}$: the average choice of agents in the same market.
- β_2: the endogenous effect, or the direct network effect.

Base Model: Identification Concerns

$$a = \beta_0 - \beta_1 P_m + \beta_2 q_m + \zeta_m + \varepsilon$$

- Omitted variables or correlation in unobserved terms across agents in the same market (ζ_m).
- Simultaneity in choices.
- More parameters than regressors $\Rightarrow$ Parameters are unidentified.

$$q_m = \beta_0 - \beta_1 P_m + \beta_2 q_m + \zeta_m$$

$$q_m = \frac{\beta_0 - \beta_1 P_m + \zeta_m}{1 - \beta_2}$$

$$a = \frac{\beta_0 - \beta_1 P_m + \zeta_m}{1 - \beta_2} + \varepsilon$$

One Solution: Consumer Heterogeneity

- If we observe individual-level explanatory variables, the situation is somewhat improved.
- ν: Demographic, such as income or individual-specific platform tax or subsidy.

$$a = \beta_0 - \beta_1 P_m + \beta_2 q_m + \beta_3 \nu + \zeta_m + \varepsilon$$

$$q_m = \frac{\beta_0 - \beta_1 P_m + \beta_3 \bar{\nu_m} + \zeta_m}{1 - \beta_2}$$

$$a = \frac{\beta_0 - \beta_1 P_m + \beta_2 \beta_3 \bar{\nu_m} + \zeta_m}{1 - \beta_2} + \beta_3 \nu + \varepsilon$$

- Intuition: Exogenous characteristics of other agents in the market ($\overline{\nu}_m$) is an IV for their choices (q_m).

Caveat: Contextual Effects

- One ignored effect: $\overline{\nu}_m$ directly affects a. $\Rightarrow$ An agent could be directly affected by the characteristics of others in the market separately from the effect of their choices a.
- Example: Peers from minority groups/wealthy classmates $\Rightarrow$ students' performance.

$$a = \beta_0 - \beta_1 P_m + \beta_2 q_m + \beta_3 \nu + \beta_4 \overline{\nu}_m + \zeta_m + \varepsilon$$

$$a = \frac{\beta_0 - \beta_1 P_m + (\beta_2 \beta_3 + \beta_4) \overline{\nu}_m + \zeta_m}{1 - \beta_2} + \beta_3 \nu + \varepsilon$$

- $\Rightarrow$ Not sufficient to identify β_2.

Solution: Random Assignment

$$a = \beta_0 - \beta_1 P_m + \beta_2 q_m + \zeta_m + \varepsilon$$

- Identification problem: Self-selection of agents into markets.
- Solution: Random assignment to markets.
- E.g. random matching of college roommates $\Rightarrow$ effects of roommate characteristics on GPA
- If selection is the only source of variation in ζ_m, random assignment can eliminate ζ_m.
  - Not usually the case: common market shocks.
  - E.g. unobserved market campaigns.

Solution: Heterogenous Networks

- Alternative way to build the model: allow agents to respond to only a subset of agents in the same market.
- $\boldsymbol{\Lambda}$: a square matrix with dimension equal to the number of agents.
  - $\lambda_{ij} = 1$ if i is affected by j and $\lambda_{ij} = 0$ otherwise.
  - Linkage between agents.

$$\boldsymbol{a} = \beta_0 - \beta_1 \boldsymbol{P} + \beta_2 \boldsymbol{\Lambda} \boldsymbol{a} + \beta_3 \boldsymbol{\nu} + \boldsymbol{\gamma} + \boldsymbol{\varepsilon}$$
$$\boldsymbol{a} = (1 - \beta_2 \boldsymbol{\Lambda})^{-1} (\beta_0 - \beta_1 \boldsymbol{P} + \beta_3 \boldsymbol{\nu} + \boldsymbol{\gamma} + \boldsymbol{\varepsilon})$$
$$\mathbb{E}[\boldsymbol{\Lambda} \boldsymbol{\alpha} | \boldsymbol{P}, \boldsymbol{\nu}] = (1 - \beta_2 \boldsymbol{\Lambda})^{-1} \boldsymbol{\Lambda} (\beta_0 - \beta_1 \boldsymbol{P} + \beta_3 \boldsymbol{\nu} + \boldsymbol{\gamma})$$

- potential instrument for $\boldsymbol{\Lambda a}$: $\boldsymbol{\Lambda \nu}$
- exogenous characteristics of connected agents $\Rightarrow$ choice of neighbors

Solution: Dynamics

$$a = \beta_0 - \beta_1 P_m + \beta_2 q_m + \zeta_m + \varepsilon$$

- Use **installed base** as the proxy for q_m.
- Rationale 1: Past choices can sometimes be treated as exogenous to current choices.
- Rationale 2: Under imperfect information, agents do not know others' current choices, and use installed base as a predictor of current choices.

Solution: Variance

- Use conditional variance instead of conditional mean to identify the existence of network effects.
- Assume there is a finite, discrete set of consumers so the average of individual shocks, $\overline{\varepsilon}_m$, does not average out.

$$q_m = \beta_0 - \beta_1 P_m + \beta_2 q_m + \zeta_m + \overline{\varepsilon}_m$$

$$a = \frac{\beta_0 - \beta_1 P_m + \zeta_m}{1 - \beta_2} + \frac{\beta_2}{1 - \beta_2} \overline{\varepsilon}_m + \varepsilon$$

- $\overline{\varepsilon}_m$ affects a only if the network effect parameter β_2 is non-zero.
- Intuition: With network effects, the choices a respond to the average shock in the market and if the variance of the average shock increases, so should the variance of a.

Indirect v.s. Direct Network Effect

- **Direct network effects:**

$$a = \beta_0 - \beta_1 P_m + \beta_2 q_m + \zeta_m + \varepsilon$$

- **Indirect network effects:**

$$a_i = \beta_{i0} - \beta_{i1} P_{im} + \gamma_i q_{jm} + \xi_{im} + \varepsilon$$

- Aggregate across agent set i:

$$q_{im} = \beta_{i0} - \beta_{i1} P_{im} + \gamma_i q_{jm} + \xi_{im}$$

- Still simultaneity problem: $\xi_{im} \Rightarrow q_{im} \Rightarrow a_j \Rightarrow q_{jm}$
- Solution: Find variables that affect one side of the market but not the other.

Example: Competitive Bottleneck

- **Competitive bottleneck:** Single-homing on one side of the market and multi-homing on the other.
- Example: Consumers only read a single newspaper but advertisers appear in multiple newspapers.
- Consumer utility:
$$u_{1m}^k = \beta_{10} - \beta_{11} P_{1m}^k + x_{1m}^k \beta_{12} + \gamma_{1m}^k q_{2m}^k + \xi_{1m}^k + \varepsilon_{1m}^k$$
- Logit form of market share s_{1m}^k, take logs:
$$ln(s_{1m}^k) - ln(s_{1m}^0) = \beta_{10} - \beta_{11} P_{1m}^k + x_{1m}^k \beta_{12} + \gamma_{1m}^k q_{2m}^k + \xi_{1m}^k$$
- Demand for the multi-homing seller side:
$$q_{2m}^k = \beta_{20} - \beta_{21} P_{2m}^k + x_{2m}^k \beta_{22} + \gamma_{2m}^k q_{1m}^k + \xi_{2m}^k$$

Competitive Bottleneck: Identification Issue

$$ln(s_{1m}^{k}) - ln(s_{1m}^{0}) = \beta_{10} - \beta_{11}P_{1m}^{k} + x_{1m}^{k}\beta_{12} + \gamma_{1m}^{k}q_{2m}^{k} + \xi_{1m}^{k}$$

$$q_{2m}^{k} = \beta_{20} - \beta_{21}P_{2m}^{k} + x_{2m}^{k}\beta_{22} + \gamma_{2m}^{k}q_{1m}^{k} + \xi_{2m}^{k}$$

- Identification problem: q_{1m}^{k} and q_{2m}^{k} are endogenous.
- Solution: Use variables in x_{im}^{k} excluded from x_{jm}^{k} to identify parameters in equation j.

Identification of Indirect Network Effect: Examples

1. Yellow Pages directories. (Rysman, 2004)
   - Consumer demand for Yellow Pages advertising. Advertiser demand for readership.
   - Advertiser-side shifter: number of people covered in a directory.
   - Consumer-side shifter: consumer demographics.
2. Digital movies & projection technology. (Caoui, 2020)
   - Consumer demand for digital movies. Movie theaters demand for digtal projection technology.
   - Uses the digital production of movies in the United States as an exogenous shifter of digital movie availability in France, as many US movies are released in France.
3. Electric vehicles & charging stations. (Li et al., 2017)
   - Gas prices affect only consumer demand. $\Rightarrow$ Identify the effect of consumers on charging stations.

Example: Yellow Pages directories (Rysman, 2004)

- Observes many markets, each populated by several Yellow Pages directories.
- Models quantities and price as choice variable.
- Simulates outcomes as the number of competing directories change.
- Result: More directories reduce market power but also dissipate network effects. The former effect dominates, so market efficiency is enhanced as the number of directory increases.

Example: German magazines (Kaiser and Wright, 2006)

- Two sides: Readers and advertisers. Both sides single-home.
- Cost shifter: Prices of publishers in related markets.
- Seesaw effect: Profits are collected largely from the advertiser side rather than the consumer side. Higher demand on the advertiser side actually reduces consumer prices as magazines seek to attract these advertisers with large readership.
- Extentions:
  - Argentesi and Filistrucchi (2007): Italian newspapers, market power.
  - Chandra and Collard Wexler (2009): Mergers between newspapers. $\Rightarrow$ The logic of two-sided markets implies that prices do not necessarily increase.
  - Jeziorski (2014): A merger results in market power that allows radio stations to lower the quantity and increase the price of advertisements.
  - Fan (2013): Quality characteristics such as news content.

Seesaw Effect

A shock that tends to raise price on one side often reduces prices on the other side.

- Seamans and Zhu (2014): newspapers with advertisement.
  - Question: How newspaper prices and outcomes respond to the entry of Craigslist, which cannibalizes classified advertisement revenue.
  - Result: Consumer prices increase and advertiser prices decrease.
  - Interpretation: The reduction in demand for classified advertisements reduces the value of consumers leading to an increase in consumer price, and the resulting reduction in readers lowers value, and thus price, to advertisers.
- Boik (2016): cable systems.
  - Two sides: content providers (e.g. local television stations) and consumers.
  - Result: Local television stations in markets with high advertisement rates set lower fees to cable systems as the advertising rates incentivize the stations to seek more consumers.
- Kay et al. (2018), Manuszak and Wozniak (2017): Payments.

Seesaw Effect (Cont'd)

Competition between firms would lead to worse prices for some agents.

- Boik (2016): cable systems.
  - In markets with more substantial competition between television delivered by cable companies and telephone companies, local television stations charge lower rather than higher fees.
  - Explanation: local television stations multi-home and the benefits of competition between platforms (cable and telephone) go to the single-homers, the consumers.
- Jin and Rysman (2015): sports card conventions.
  - Two sides: Buyers and sellers of sports memorabilia. Take convention organizer as the platform.
  - Observe prices charged to each side at thousands of conventions.
  - Finding: Pricing responds to competition between platforms much more on the single homing side. About 50% of conventions offer free admission to consumers.