Dynamic Product Positioning in Differentiated Product Markets: The Effect of Fees for Musical Performance Rights on the Commercial Radio Industry
A. Sweeting (Econometrica, 2013)

Yulia Dudareva, Olga Kiseleva, Phoebe Tian

University of Wisconsin-Madison

October 9th, 2017

Motivation

- Performance Rights Act (2009): music radio stations should pay for musical performance rights
- **Goal**: develop and estimate a dynamic discrete-choice model of format choice to predict how much format variety would change if fees of 10% or 20% of revenues were introduced
- Static models to predict how specific policy-interventions or mergers would affect product characteristics: Fan (2012), Nishida (2012), and Datta and Sudhir (2012)
- Dynamic model to understand the benefits and costs of radio mergers: Jeziorski (2013)

Empirical regularities

Data: 102 local radio markets from 2002-2005 (BIAfn; BIA Financial Network (2006))

- Listeners with different demographic characteristics have different tastes. Music stations have higher audience shares
- Advertisers have different values on listeners with different demographics
- Only one station permanently closes, and 55 stations begin operating
- The average owner in a market operates 2.5 stations with some clustering in the same format

Model

Setup

- Radio station owners (firms) $o = 1, \ldots, O_m$ in each market m play an infinite horizon game. Firm o owns a set of stations S^o, with $F = 0, 1, \ldots, 7$ discrete formats to choose from.
- Each station's quality consists of:
  - Observed quality X_{st} with effects γ^s.
  - Unobserved quality ξ_{st}, independent of observed quality, and evolving according to an AR(1) process:

$$\xi_{st} = \rho \xi_{st-1} + v_{st}^{\xi} + \gamma^{\xi} \cdot \mathbb{1}_{\{F_{st} \neq F_{st+1}\}} \quad (1)$$

- Firms generate revenues by selling their audiences to advertisers. The audience is determined by a static discrete choice random coefficients logit model:

$$u_{ist} = \gamma_i^R + X_{st}\gamma^s + F_{st}(\bar{\gamma}^F + \gamma_D^F D_i) + \xi_{st} + \epsilon_{ist}^L \quad (2)$$

  and the advertising revenue for a listener with demographics D_d is determined by $r_{st}(D_d) = \gamma_m(1 + Y_{st}\gamma^Y)(1 + D_d\gamma_d)$

Model

Timing and Flow Profit Functions

- Each firm o observes the publicly observed state $M_{j,o,t}$, and pays fixed costs reduced by $C(M_{j,o,t})\theta^C$ for operating multiple stations in the same formats
- Each firm o observes its ϵ_{ot}, distributed Type 1 extreme value and scaled by θ^ϵ, and makes format choice $a_{ot} \in A_o(M_{j,o,t})$
- Each firm o receives advertising revenues $\sum_{s \in S^o} R_s(M_{j,o,t}|\gamma)$, pays repositioning costs $W_o(a_{ot})\theta^W$ and receives $\theta^\epsilon \epsilon_{ot}(a_{ot})$

Define a firm's flow payoff as:

$$\pi_{ot}(a_{ot}, M_{j,o,t}, \theta, \gamma) + \theta^\epsilon \epsilon_{ot}(a_{ot}) = \underbrace{\sum_{s \in S^o} R_s(M_{j,o,t}, \gamma)}_{\text{advertising revenues}} + \underbrace{\beta C(M_{j,o,t})\theta^C}_{\text{fixed cost saving next period}} - \underbrace{W_o(a_{ot})\theta^W}_{\text{repositioning costs}} + \underbrace{\theta^\epsilon \epsilon_{ot}(a_{ot})}_{\text{payoff shock}} \quad (3)$$

Model

Value Functions and Equilibrium Concept

Firms are assumed to use stationary Markov Perfect Nash Equilibrium in pure strategies

$$V_o^{\Gamma}(M_{j,o,t},\epsilon_{ot}) = \max_{a\in A_o(M_{j,o,t})}\Big\{\pi(a,M_{j,o,t}) + \theta^{\epsilon}\epsilon_{ot}(a)$$
$$+\beta\int V_o^{\Gamma}(M_{j,o,t+1})f(M_{j,o,t+1}|a,\Gamma_{-o},M_{j,o,t})dM_{j,o,t+1}\Big\}$$

Given the distribution of payoff shocks, the CCPs are:

$$P^{\Gamma_o}(a,M_{j,o,t},\Gamma_{-o}) = \frac{exp(\frac{v_o^{\Gamma}(a,M_{j,o,t},\Gamma_{-o})}{\theta^{\epsilon}})}{\sum_{a'\in A_o(M_{j,o,t})} exp(\frac{v_o^{\Gamma}(a',M_{j,o,t},\Gamma_{-o})}{\theta^{\epsilon}})} \quad (4)$$

Identification

Identification of Primitives

- Demand: Random Coefficient Logit Model:

$$u_{ist} = \gamma_i^R + X_{st}\gamma^s + F_{st}(\bar{\gamma^F} + \gamma_D^F D_i) + \xi_{st} + \epsilon_{ist}^L$$

  37 moment restrictions for 37 parameters

- Revenues:

  $$r_{st}(D_d) = \gamma_m + \gamma_m \gamma_d D_d + \gamma_m \gamma^Y Y_{st} + \gamma_m \gamma^Y Y_{st} D_d \gamma_d$$

- Demographic transition:

$$\log(\frac{pop_{met}}{pop_{met-1}}) = \tau_0 + \tau_1 \log(\frac{pop_{met-1}}{pop_{met-2}}) + u_{met}$$

Identification

Identification of Primitives

- Normalization: $\pi = 0$ for "temporarily off-air format"
- Initial Choice Probabilities:

$$P_o^i(a|\mathcal{M}_{jot}) = \frac{exp\left(\frac{v_0^\Gamma(a, \mathcal{M}_{jot}, \Gamma_{-0})}{\theta^\varepsilon}\right)}{\sum_{a' \in \mathcal{A}_o(\mathcal{M}_{jot})} exp\left(\frac{v_0^\Gamma(a', \mathcal{M}_{jot}, \Gamma_{-0})}{\theta^\varepsilon}\right)}$$

- Payoffs:

$$\pi_{ot}(a_{ot}, M_{j,o,t}, \theta, \gamma) + \theta^\epsilon \epsilon_{ot}(a_{ot})$$
$$= \sum_{s \in S^o} R_s(M_{j,o,t}, \gamma) + \beta C(M_{j,o,t})\theta^C - W_o(a_{ot})\theta^W + \theta^\epsilon \epsilon_{ot}(a_{ot})$$

  - θ^ε is identified since revenues are treated as observable

Identification

Identification of Counterfactuals

- Systematic part of the payoff:

$$\tilde{\pi}(P_o^i(\mathcal{M}_{jot}), \theta^i) = \sum_{s \in S^o} R_s(\mathcal{M}_{jot}|\gamma) + \sum_{a \in \mathcal{A}_o(\mathcal{M}_{jot})} P_o^i(a|\mathcal{M}_{jot}) \times$$
$$\left(\beta C_o(a)\theta^{Ci} - W_o(a)\theta^{Wi} + \theta^{\varepsilon i}(\varkappa - log(P_o^i(a|\mathcal{M}_{jot}))\right)$$

  where $\varkappa$ is Euler constant

- depends only on CCPs, so, it is identified (Hotz-Miller invertion theorem)
- Aguirregabiria (2005):

  Counterfactual optimal choice probabilities are identified if (1) the discount factor, (2) the distribution of unobservables, (3) the flow payoff differences are also known

Estimation

Step 1: Estimate γ and ξ

- Random-coefficient demand model (GMM to avoid potential endogeneity) $\Rightarrow$ infer ξ by Berry and Nevo algorithm
- Revenue function (NLLS)
- Firm's initial CCP's (multinomial logit)
- Demographics transition process (2SLS)

Step 2: Estimate θ

- Value Function approximation (parametric and forward simulation)
  value functions are approximated by a linear function of K functions (ϕ) of a specific set of N states:

$$V_o^P(M_{j,o,t}) \simeq \sum_{k=1}^{K} \lambda_k \phi_{ko}(M_{j,o,t})$$

Estimation

Step 2

1. Compute payoffs from γ, CCPs and current guess of θ:

$$\tilde{\pi}(P^i_o(\mathcal{M}_{jot}),\theta^i) = \sum_{s\in S^o} R_s(\mathcal{M}_{jot}|\gamma) + \sum_{a\in\mathcal{A}_o(\mathcal{M}_{jot})} P^i_o(a|\mathcal{M}_{jot})\times \left(\beta C_o(a)\theta^{Ci} - W_o(a)\theta^{Wi} + \theta^{\varepsilon i}(\varkappa - log(P^i_o(a|\mathcal{M}_{jot}))\right)$$

2. Compute parameters of approximation λ
3. Use λ to get future value of each firm when it chooses a
4. Estimate θ' by MLE

$$P^i_o(a|\mathcal{M}_{jot}) = \frac{exp\left(\frac{FV(a,\mathcal{M}_{jot},P^i_o) - W_o(a)\theta^W + \beta C_o(a)\theta^C}{\theta^\varepsilon}\right)}{\sum_{a'\in\mathcal{A}_o(\mathcal{M}_{jot})} exp\left(\frac{FV(a',\mathcal{M}_{jot},P^i_o) - W_o(a')\theta^W + \beta C_o(a)\theta^C}{\theta^\varepsilon}\right)}$$

5. Use θ' to update CCPs

Asymptotics

Step 1: Estimate γ and ξ

- Listener demand: (random coeeficient model estimated by GMM) consistent and converges with $\sqrt{N}$ under standrd assumptions
- Revenue function (NLLS), Demographics (2SLS) are consistent and converges with $\sqrt{N}$
- CCP's are estimated by MLE (multinomial logit): estimates are consistent; rate of convergence is $\sqrt{N}$ (CLT holds)

Step 2: Estimate θ

- Value function approximation:
  PMLE gives consistent and $\sqrt{N}$-converging estimates for θ (Aguirregabiria and Mira, 2007) if CCPs estimates are consistent and $\sqrt{N}$-converging.

- Standard errors are calculated using a bootstrap
- Estimates are more efficient since outside information is used

Results

- Dynamic discreet-choice model of a format choice allowing for
  - vertical and horizontal differentiation
  - heterogenous customers' tastes and their different values to the advertisers
  - multi-station ownership
- after 20 years:
  - **10% fees** reduce the number of music stations by **9.4%** (music listening falls by 6.3%)
  - **20%** fees reduce the number of music stations by **20%** (music listening falls by **13.4%**)
- **Not as dramatic decline as predicted**: many valuable listeners prefer music programming to non-music one
- **Long-run adjustment takes place pretty quickly**: for both 10% and 20% fee, at least 40% of long-run change in the number of stations is completed within 2.5 years

Summary

- What determines product variety: Borenstein and Netz (2002), George and Waldfogel (2003), Watson (2009) ⇒ **natural model for oligopoly**
  - radio industry: Berry and Waldfogel (2001) and Sweeting (2010).
- Static structural models predicting how policy-interventions or mergers affect product characteristics: Fan (2012), Nishida (2012), and Datta and Sudhir (2012) ⇒ **dynamic model with non-immediate adjustment** (effect and speed of adjustment)
- Justified implementation of either value function approximation method for large state spaces required for studying an industry's evolution