ECON 7130 - Microeconomics III

Spring 2015

Notes for Acemoglu and Linn (*Quarterly Journal of Economics*, 2004)

Question:

- Do increases in market size spur innovation in the pharmaceutical industry?

Tools:

- Continuous time dynamic programming
- Monopolistic competition
- Free entry
- Poisson model
- Quasi-maximum likelihood

Outline of Model

1. Specification of Environment
   (a) Population of agents
      - Continuum of drug consumers
         – J groups defined by drug demanded
      - Continuum of firms who are monopolistically competitive
         – Free entry of new firms
         – Identify firms by the best quality drug they produce in each line $j \in J$
   (b) Preferences
      - Consumers:
         – Forward looking with infinite time horizon
         – Consumers of group G_j get utility from basic good y and drug j
         – Specifically, agents choose the sequence of consumption of the basic good, $c_i(t)$, and drug j, $x_{ij}(t)$, to maximize:

$$\int_0^\infty exp(-rt)[c_i(t)^{1-\gamma}(q_j(t)x_{ij}(t))^\gamma]dt, \tag{1}$$

           where r is the real interest rate and $q_j(t)$ is the time varying quality of drug j
         – Consumers make these choices subject to their per period budget constraint:

$$c_i(t) + p_j(t)x_{ij}(t) = y_i(t), \tag{2}$$

           where $y_i(t)$ is the exogenous endowment to agent i at time t
         – Note that the fact that there is no borrowing/saving really simplifies the consumer's problem.
      - Producers:
         – Forward looking with infinite time horizon
         – Firms are monopolistically competitive
         – Set price to capture market

  - Per period profit function: $\pi_j(p_j(t), q_j(t)) = p_j(t)X_j(t) - mc_j(t)X_j(t)$ (big X denotes market demand)

(c) Production technology

- Use basic good y to produce drugs
  - Marginal cost of production = 1 unit of basic good
- Can also spend money on R&D
  - Spending is targeted at drugs of type j
  - If spend $z_j(t)$ units of basic good on R&D, the flow rate of new drugs (innovations) is:

$$n_j(t) = \delta_j z_j(t) \tag{3}$$

  - Innovation results in a drug with quality $\lambda q_j(t)$ where $\lambda > 1$ and $q_j(t)$ is highest quality existing drug in line j

(d) Information technology

- Full info in basic model
- Extensions in other versions consider uncertainty in market size

(e) Enforcement technology

- N/A

(f) Matching technology

- Decentralized, competitive market where consumers and producers meet

2. Equilibrium

- Recursive monopolistically competitive eq'm
  - Firms compete on price for differentiated product
  - Free entry results in zero profits in equilibrium

Model outline:

- Consumers demand drugs corresponding to their type and income
- Firms compete to sell drugs, choosing price and investing in R&D to get leading technology/quality
- Firm's decision to invest in R&D will be a function of expected profits, which are a function of market size

Demand:

- Cobb-Douglas utility function (and no borrow/save) implies demand from consumer i of group G_j at time t is $x_{ij}(t) = \frac{\gamma y_i(t)}{p_j(t)}$
  - Note how quality falls out of this demand equation
  - Get this from FOC. Subbing in for $c_i(t) = y_i(t) - p_j(t)x_{ij}(t)$ from BC, we have:

$$\begin{aligned}\frac{\partial U}{\partial x_{ij}(t)} = e^{-rt[\cdot]} \big[&(1-\gamma)(-p_j(t))(y_i(t) - p_j(t)x_{ij}(t))^{-\gamma}(q_j(t)x_{ij}(t))^{\gamma} + \\ &(y_i(t) - p_j(t)x_{ij}(t))^{1-\gamma}\gamma q_j(t)(q_j(t)x_{ij}(t))^{\gamma-1}\big] = 0\end{aligned} \tag{4}$$

- Which means that:

$$\left[(1-\gamma)(-p_j(t))(y_i(t)-p_j(t)x_{ij}(t))^{-\gamma}(q_j(t)x_{ij}(t))^{\gamma}+(y_i(t)-p_j(t)x_{ij}(t))^{1-\gamma}\gamma q_j(t)(q_j(t)x_{ij}(t))^{\gamma-1}\right]=0$$
$$\iff (1-\gamma)(p_j(t))(y_i(t)-p_j(t)x_{ij}(t))^{-\gamma}(q_j(t)x_{ij}(t))^{\gamma}=(y_i(t)-p_j(t)x_{ij}(t))^{1-\gamma}\gamma q_j(t)(q_j(t)x_{ij}(t))^{\gamma-1} \quad (5)$$

- Solving the above for $x_{ij}(t)$ yields: $x_{ij}(t)=\frac{\gamma y_i(t)}{p_j(t)}$

- Market demand for drug j at time t is thus: $X_j(t)=\frac{\gamma Y_j(t)}{p_j(t)}$
  - Where $Y_j(t)=\sum_{i\in G_j} y_i(t)$
  - Thus, $Y_j(t)$ determines the size of the market for drug j

Supply:

- Monopolistic competition means that $p_j(t)$ for the highest quality drug is given by $p_j(t)=\lambda$
  - Where λ is the proportional increase in quality in the best quality drug resulting from a new innovation
  - This pricing rule is derived from the difference in consumer utility between the best quality drug and the next best quality drug
    - Solve for this by using the individual demand above and solving for utility of best and next best quality. Solve for price that makes these two equal..
  - If the price is higher than this, the consumer will chose the next best quality drug - no sales for best quality

- This implies that per period profits are given by:
  - $\pi_j(p_j(t),q_j(t))=p_j(t)X_j(t)-mc_j(t)X_j(t)$
  - $\pi_j(p_j(t),q_j(t))=p_j(t)X_j(t)-X_j(t)$
  - $\pi_j(q_j(t))=\lambda X_j(t)-X_j(t)$
  - $\pi_j(q_j(t))=(\lambda-1)X_j(t)$
  - $\pi_j(q_j(t))=(\lambda-1)\frac{\gamma Y_j(t)}{\lambda}$
  - Note: I'm not sure how they get rid of the λ in the denominator
  - A+L write: $\pi_j(q_j(t))=(\lambda-1)\gamma Y_j(t)$

- Which means that the discounted present value of having the highest quality drug j at time t is given by:

$$rV_j(t|q_j)=\pi_j(q_j(t))+\underbrace{\dot{V}_j(t|q_j)}_{\text{Potential gain/loss in value}}-\underbrace{\underbrace{\delta_j z_j(t)}_{n_j(t)}V_j(t|q_j)}_{\text{Accounts for other firms investing in drug } j \text{ and becoming leader in quality}} \quad (6)$$

  - Note that firm with highest quality drug won't innovate (This is a result of Arrow (1962), though my reading just says that they have less incentive to innovate)

- Free entry means that profits are zero
  - This means that $\pi_j(t)=z_j(t)$ - all potential profits are spent on R&D
  - If $\pi_j(t)=z_j(t)$, then profits are zero and $\pi_j(t)=\delta_j z_j(t)V_j(t|q_j)$, which means $z_j(t)=\delta_j z_j(t)V_j(t|q_j)$, which means $1=\delta_j V_j(t|q_j)$
  - Thus:

    - If $z_j(t) > 0$, then $\delta_j V_j(t|q_j) = 1, \ \forall j, t$
    - If $z_j(t) = 0$, then $\delta_j V_j(t|q_j) \leq 1, \ \forall j, t$ (no eq'm R&D - no money spent because no expected profits)
  - To find amount of R&D do:
    - If $z_j(t) > 0$, then $\delta_j V_j(t|q_j) = 1$ and $\dot{V}_j(t|q_j) = 0$
    - $\Rightarrow rV_j - 0 = \pi_j(q_j(t)) - z_j$
    - $\Rightarrow z_j = \pi_j(q_j(t)) - rV_j(t|q_j)$
    - $\Rightarrow z_j = \frac{\delta_j \pi_j(q_j(t))}{\delta_j} - \frac{r \overbrace{\delta_j V_j(t|q_j)}^{=1}}{\delta_j}$
    - $\Rightarrow z_j = \frac{\delta_j \pi_j(q_j(t)) - r}{\delta_j}$
    - $\Rightarrow z_j = \frac{\delta_j (\lambda - 1)\gamma Y_j(t) - r}{\delta_j}$
    - Thus, $z_j = max \left\{ \frac{\delta_j (\lambda - 1)\gamma Y_j(t) - r}{\delta_j}, 0 \right\}, \ \forall j, t$
  - This leads to some comparative statics that are of interest:
    - $\frac{\partial z_j(t)}{\partial Y_j(t)} > 0$; Bigger market means more R&D
    - $\frac{\partial z_j(t)}{\partial \lambda} > 0$; Larger innovations means more R&D
    - $\frac{\partial z_j(t)}{\partial \delta_j} > 0$; More productive R&D means more R&D
    - $\frac{\partial z_j(t)}{\partial r} < 0$; Higher interest rate means less R&D (b/c R&D pays off in future)
    - $\frac{\partial z_j(t)}{\partial \gamma} > 0$; Bigger market means more R&D
  - Expend on R&D + technology (δ_j) $\Rightarrow$ the rate of entry of new drugs: $n_j(t) = max \left\{ \delta_j (\lambda - 1)\gamma Y_j(t) - r, 0 \right\}$

Equilibrium:

- Defined by:
  - $p_j(t)|j = 1, ..., J$
  - $X_j(t)|j = 1, ..., J$
  - $z_j(t)|j = 1, ..., J$
- That are consistent with individual utility maximization, firm profit maximization, and the market clearing conditions.

Identification:

- Not structural, but use model eq'm for innovation to generate empirical model
- Add to this some controls
- Use a Poisson model because distribution of arrival of new innovations
  - Poisson distribution is generally what you want to use to model arrival times
- Problem: can't observe the δ_j's
- Model estimated using linear regressions as well as multinomial logit model estimates with quasi-maximum likelihood (better properties if model misspecified)

Data:

- Need data on market size, innovations
- Market size:
  - Demographics from the CPS
  - Drug expenditures form MEPS (Medical Expenditures Panel Study)
- Innovations:
  - FDA drug approval data
  - Consider various measures of innovation: generics, non generics, new molecular entities

Results:

- Market size increases innovations using a number of measures

Strengths:

- Pretty clear model of innovation
- Not shown, but apparently they have one that allows for transitional dynamics so get innovation in anticipation of market size change
- Nice transition from theory to data
- Thorough robustness checks

Weaknesses:

- Still trouble with δ_j's - even with all robustness checks. What if R&D productivity increasing as baby boomer's age? Spurious correlation...