Quality Ladders, Competition and Endogenous Growth

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The Conventional View

- standard growth model: persistent growth requires increasing returns to scale (at the economy wide level)
- led to “Schumpeterian” models of quality ladders with increasing returns to scale at the firm/plant level driven by short-term monopoly power
- but with infinitely many goods on quality ladder, persistent growth is consistent with decreasing or constant returns to scale
- competitive diminishing returns models explain the same facts as “Schumpeterian” models
- competitive diminishing returns models are driven by the benefit of expanding on a particular rung of the quality ladder before moving up the ladder
- the facts favor the competitive diminishing return model
Our Story

- each innovation opens door to growth on a new rung of the quality ladder
- as opportunities opened by an innovation are exhausted becomes both socially and privately optimal to introduce a new innovation
- fixed costs and monopoly power may exist as an empirical matter but play no essential theoretical role
- existing theory: after radio invented everyone moves immediately to inventing television
- our theory: after radio invented everyone spends resources improving and expanding the production of radios – only after the radio widespread, and gains to further improvement and expansion became small do people move on to invent/produce television
- our story is of course the rule not the exception
The Grossman-Helpman Model

\[ U = \int_0^\infty e^{-\rho t} \log \left[ \sum_j \lambda^j d_{jt} \right] dt \]

- One unit of output requires a unit of labor to obtain.
- The first to reach \( j \) has monopoly until \( j + 1 \) is reached.
- R&D intensity is \( \tilde{\iota} \), probability of innovating is \( \tilde{\iota} dt \) at a cost of \( \tilde{\iota} a_I dt \).
- One unit of labor, \( E \) steady state expenditure
- Wage rate is numeraire and price is \( \lambda \) because of limit pricing
- The resource constraint is \( a_I t + E / \lambda = 1 \).
Solution

solve for steady state research intensity

$$\iota = \frac{(1 - 1/\lambda)}{a_I} - \frac{\rho}{\lambda}$$

solve also for social optimum research intensity

$$\iota^* = \frac{1}{a_I} - \frac{\rho}{\log \lambda}.$$
Climbing the Ladder under Competition

profitable to introduce a new good only when the quantity of the old is large enough to make its price low relative to that of the new one

Irwin and Klenow [1994]: DRAM memory chip, different qualities correspond to capacity of a single chip
production of new vintage does not jump up instantaneously, ramps up gradually, new quality introduced when the stock of the old one is large old vintage phased out gradually as new introduced
price of each vintage falls roughly exponentially

so incentive to introduce the next generation chip keeps increasing
Innovation with Knowledge Capital

- Retain preferences, endowment, and ladder structure
- A step on the ladder corresponds **both** to knowledge capital (KC) $k_j$ and consumption $d_j$
- Consumption needs labor **and** capital
- KC has two uses: more KC and consumption
- More KC = increasing own type or creating new type
Uses of Knowledge Capital

Same type produced at a fixed rate $b > \rho$, widening, imitating

New type $j + 1$ needs $a > 1$ units of quality $j$, deepening, innovating

Deepening is costlier than widening, $\lambda / a < 1$

Law of motion:

$$\dot{k}_j + h_j = b(k_j - d_j) + \frac{h_{j-1}}{a}.$$ 

Allow $\Delta k_{j+1} = -\Delta k_j / a$

*This is an ordinary diminishing return economy: first and second welfare theorems hold; efficient allocations can be decentralized as a competitive equilibrium and vice versa*
**The Innovation Cycle**

Diminishing returns: competitive equilibrium is efficient

Production uses at most two adjacent qualities of capital \( j - 1, j \)

Innovate only when necessary, that is when \( d_j = 1 \)

During deepening consumption is constant (build up phase)

During widening consumption grows at \( b - \rho \) (growth phase)

Equilibrium paths cycle between widening and deepening

Prices of knowledge capital fall at a constant rate \( b - \rho \)

\[
j^* = \frac{b - \rho}{\log a}
\]

next from Alexander Monge-Naranjo
Figure 1: Consumption of different vintages in Boldrin-Levine
Figure 2: Evolution of Knowledge Capital of different vintages
Fixed Cost of Knowledge Capital

there might be a fixed cost of creating new knowledge
also fixed costs in producing just about everything: doesn’t prevent
divisible model from being a useful tool
robustness of model of competitive innovation to fixed costs?
in this model there is an $F^* > 0$ such that when innovation takes place
a mass of $F^*$ units of old knowledge capital is converted to the new
knowledge capital
as long as the fixed cost is less than $F^*$ it plays no role