

Innovation and Growth with Financial, and Other, Frictions

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Motivation

- New ideas and the advance of knowledge are key for economic performance and growth.
- Two big issues
 - Production: How to generate the efficient number of ideas?
 - Exchange: How to get ideas into the hands of those best suited to implement them (technology transfer)?
- This process is not frictionless:
 - Private cost vs. long term social benefit
 - Search frictions and bargaining frictions
 - Liquidity/financial frictions

We build a growth model where advances in knowledge lead to increases in productivity

- Individual producers have access to the frontier technology Z , which is in the public domain.
- They also come up with ideas for innovations that increase their own knowledge and productivity z .
- Ideas can also be transferred to others who may be better at implementation and development.
- Search, bargaining and financial frictions impede this market, hindering innovation and growth.
- We show that financial intermediation helps and explain why.

A Short Sample of Related Work

- Ideas and Growth:
 - Romer (1990), Jones (1997), Kortum (1997), Alvarez et al. (2008), Lucas (2009), Lucas and Moll (2011).
- Transfer of Ideas:
 - Holmes and Schmitz (1990), Chatterjee and Rossi-Hansberg (2010), Silveira and Wright (2010), Chiu and Meh (2011).
- Financial Development and Growth:
 - Goldsmith (1967), Greenwood and Jovanovic (1990), Levine (2004), Greenwood et al. (2008, 2010).
- Monetary Policy and Growth:
 - Gomme (1993), Boyd and Champ (2003), Berentsen et al. (2009).

Basic Growth Model

Environment

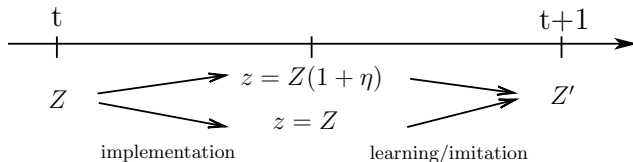
- Infinite horizon: $t = 1, 2, 3, \dots$
- Measure 1 of agents
 - ◊ n_i potential innovators
 - ◊ n_e potential entrepreneurs
 - ◊ $1 - n_i - n_e$ others
- Preferences: $\log c - \chi h$
- Technology: $y = z f(H)$
- Here, we abstract from capital K , but see paper
- Lucas tree A with dividend normalized to $\delta = 1$

Innovation

- At the start of t , all agents have access to Z .
- Innovators come up with a new idea every period.

$$z = \begin{cases} Z(1 + \eta) & \text{w/prob. } \sigma \\ Z & \text{w/prob. } 1 - \sigma \end{cases}$$

- $\sigma \sim F_i(\sigma)$ captures the match between idea and skill



Diffusion

- In general, Z' depends on entire distribution of z_j .
- An Example: CES diffusion

$$Z' = \rho \left(\int z_j^\varepsilon dj \right)^{\frac{1}{\varepsilon}}$$

- ◇ $\varepsilon = \infty$: frontier determined by the most productive.
- ◇ $\varepsilon = -\infty$: frontier determined by the least.
- ◇ $\varepsilon = 1$: frontier technology determined by average.

Agent's Problem

$$W(a, z; Z) = \max_{c, h, a'} \{u(c) - \chi h + \beta V(a', Z')\}$$

subject to

$$c + \phi a' = wh + (\phi + Z)a + \pi(z),$$

$$\pi(z) = \max_H \{zf(H) - wH\},$$

$$V(a, Z) = \mathbb{E}\sigma W[a, Z(1 + \eta); Z] + (1 - \mathbb{E}\sigma)W(a, Z; Z).$$

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Gain from implementing:

$$\Delta = W[a, Z(1 + \eta); Z] - W(a, Z; Z) = (\pi_1 - \pi_0) \frac{\chi}{w}$$

Equilibrium

Equilibrium is a list of prices (ϕ, w) and quantities (c_j, h_j, H_j, a'_j) for each agent j such that

1. Given prices, quantities agents' problem for each j
2. Market clearing

$$\begin{aligned}\int c_j dj &= \int z_j f(H_j) dj + AZ \\ \int H_j dj &= \int h_j dj \\ \int a'_j dj &= A\end{aligned}$$

Balanced Growth

Balanced Growth: $\bar{H} = \bar{H}'$ and

$$1 + g = \frac{Z'}{Z} = \frac{C'}{C} = \frac{w'}{w} = \dots$$

Prop. $\exists!$ balanced growth equil, where $1 + g = G(N)$

$$N = n_i \mathbb{E}\sigma = n_i \int \sigma dF_i(\sigma)$$

In the example with CES diffusion

$$G(N) = \rho [N(1 + \eta)^\varepsilon + 1 - N]^{1/\varepsilon}$$

Endogenous Innovation

- Remark: So far $1 + g = G(N)$ is purely mechanical.
- Endogenous Innovation: cost κ_i to come up with an idea.
- Free entry:

$$n_i = \begin{cases} 0 & \text{if } \kappa_i > \Delta \mathbb{E}\sigma \\ [0, \bar{n}_i] & \text{if } \kappa_i = \Delta \mathbb{E}\sigma \\ \bar{n}_i & \text{if } \kappa_i < \Delta \mathbb{E}\sigma \end{cases}$$

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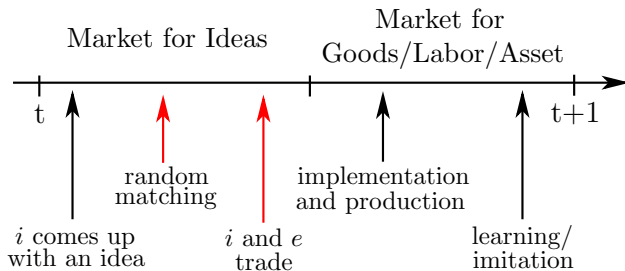
- **Prop:** $\exists!$ equil, where g depends on κ_i, F_i, \dots , but not A . It is not efficient, unless we subsidize innovation by

$$\tau_i = \frac{G'(N)\mathbb{E}\sigma}{G(N)r} > 0.$$

Tech Transfer with Perfect Credit

Entrepreneurs

- Introduce measure n_e of entrepreneurs (endogenize later)
- Entrepreneurs do not innovate, but may be better at implementing ideas: $\sigma_e \sim F_e(\sigma_e|\sigma_i)$.



- CRS matching technology: $\mu = \mu(n_i, n_e)$
- Terms of trade determined by Nash bargaining.

$$p(\sigma_e, \sigma_i) = \Delta[\theta\sigma_i + (1 - \theta)\sigma_e]$$

- Growth rate is still $1 + g = G(N)$, but

$$N = n_i \mathbb{E}\sigma_i + \mu(n_i, n_e)\Sigma,$$

where $\Sigma = \int_{\sigma_e > \sigma_i} (\sigma_e - \sigma_i) dF(\sigma_e, \sigma_i)$

Two-Sided Entry

- **Prop.** $\exists!$ equil, where g depends on $\kappa_i, \kappa_e, F_i, F_e, \dots, \theta$, but not A .

It is not efficient, unless

$$\tau_e = \tau_e^* \equiv \frac{G'(N)\mu_e\Sigma}{rG(N)} - u'(c) Z\Delta\Sigma \frac{\mu}{n_e} (\theta - \theta^*)$$

$$\tau_i = \tau_i^* \equiv \frac{G'(N)(\mathbb{E}\sigma_i + \mu_i\Sigma)}{rG(N)} - u'(c) Z\Delta\Sigma \frac{\mu}{n_i} (\theta^* - \theta)$$

where $\theta^* = \frac{\mu_e n_e}{\mu}$ (Hosios cond.)

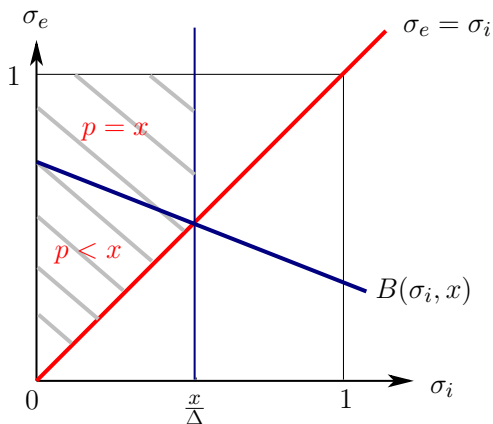
- 1st term corrects the knowledge externality
- 2nd term corrects the search externality

Tech Transfer with Constrained Credit

Liquidity

- A fraction $A_1 = \gamma A$ of the assets are liquid.
 - ◇ claims to A_1 can be used as collateral to secure credit in the idea market (Kyotaki-Moore)
 - ◇ claims to A_1 can be used as a means of payment in the idea market (Kyotaki-Wright)
- Bargaining is as above except

$$p \leq x \equiv a_1 = \frac{\phi + Z}{Z}$$



Trade iff $\sigma_e \geq \sigma_i$ and $\frac{x}{\Delta} \geq \sigma_i$. (note: x and Δ are endogenous).

Result

- Growth rate is still $1 + g = G(N)$, but

$$N = n_i \mathbb{E} \sigma_i + \underbrace{\mu(n_i, n_e) \int_{\min\{\sigma_e, \frac{x}{\Delta}\} > \sigma_i} (\sigma_e - \sigma_i) dF(\sigma_e, \sigma_i)}_{\text{Additional success due to trade}}$$

- **Prop.** For fixed $(n_i, n_e) \exists!$ equilibrium where g depends on $\kappa_i, \dots, \theta, A_1$.

In particular,

- ◇ an increase in A_1 leads to higher x, N, g
 - ◇ an increase in θ leads to higher x, N, g
- low $A_1 \Rightarrow \phi >$ fundamental price, a liquidity premium or bubble

Two-sided Entry

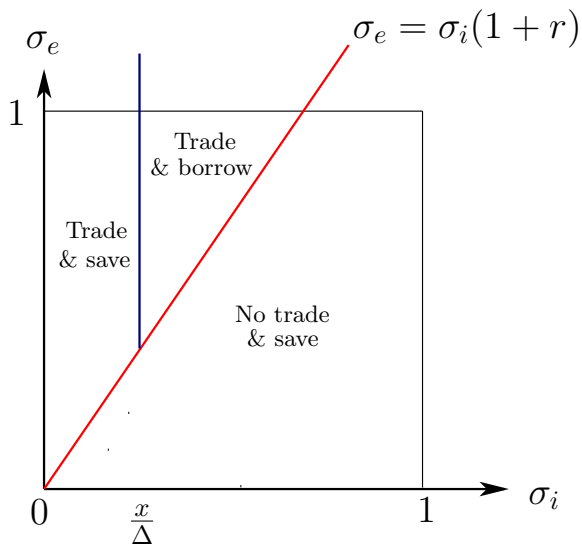
Prop. With endogenous (n_i, n_e) , equilibrium is generally inefficient, unless:

1. The subsidies are set to $\tau_i = \tau_i^*, \tau_e = \tau_e^*$
2. The supply of liquid assets is abundant $A_1 \geq A^*$;
3. Entrepreneurs have all the bargaining power, $\theta = 1$.

Tech Transfer with Intermediated Credit

Intermediated Credit

- Competitive financial intermediaries, banks, are open at the same time as the idea market.
- As in Berentsen et al. or Diamond Dybvig, banks allows agents to allocate liquidity more efficiently.
- Depending on match (σ_i, σ_e) , e may supply or demand loans of liquid assets through intermediaries.
- Interest rate r adjusts to clear the market.



Main Result

Prop. With endogenous innovation, equilibrium is inefficient, unless:

- ◇ The subsidies are set to $\tau_i = \tau_i^*, \tau_e = \tau_e^*$;
- ◇ The supply of liquid assets is abundant $A_1 \geq A^{**}$.

Remark 1: $A^{**} < A^*$ – intermediation allows us to economize on liquid assets

Remark 2: we do not need $\theta = 1$, as we did in the model w/o banks
– intermediation eliminates holdup problem

Conclusion

- We study four regimes: No credit, Perfect credit, Constrained credit, and Intermediated credit
 - ◊ NC $\Rightarrow N = n_i \bar{\sigma}_i$
 - ◊ PC $\Rightarrow N = n_i \bar{\sigma}_i + \mu \int_{\sigma_e > \sigma_i} (\sigma_e - \sigma_i) dF$
 - ◊ CC $\Rightarrow N = n_i \bar{\sigma}_i + \mu \int_{x/\Delta, \sigma_e > \sigma_i} (\sigma_e - \sigma_i) dF$
 - ◊ IC $\Rightarrow N = n_i \bar{\sigma}_i + \mu \int_{\sigma_e > (1+r)\sigma_i} (\sigma_e - \sigma_i) dF$
- Intermediation helps economize on liquidity and eliminate holdup problem.

What is an Idea?

1. Inputs into the expansion of knowledge, improving productivity.
2. Ideas are indivisible – either I tell you or I don't (mainly a technical consideration).
3. Ideas is non-rival goods at least in the long run when knowledge enters the public domain (can be non-rival in the short run too).
4. Ideas are difficult to collateralize, making credit problematic and motivating the consideration of liquidity.
5. The idea market is rife with information problems, motivating a general desire to transfer ideas directly.

Innovation and Technology Markets

Lamoreaux and Sokoloff (1999) examined US patent history in 1840-1920 and argued

“There is, in our view, good reason to believe that it was the expanded opportunities to trade in the rights to patented technologies that enabled the independent inventors of this golden age to flourish, and that stimulated the growth of inventive activity more generally. Early nineteenth-century inventors generally took personal responsibility for the commercial development of their ideas, making it difficult for them to focus exclusively on the generation of new technologies. As institutions emerged to facilitate the sale or transfer of patent rights to other individuals or firms better positioned to commercially exploit them, however, many inventors increasingly took advantage of this avenue for extracting the returns to their efforts and concentrated on inventive activity. In other words, the growth of market trade in patents raised the returns to invention generally, and encouraged a division of labor whereby technologically creative individuals increasingly specialized in their comparative advantage – invention.”

Search Cost in Technology Markets

*“... the growth of technology trade in the United States in the nineteenth century was accompanied and sustained by the growth of patent attorneys, patent agents, and other services that helped bring buyers and sellers together. Patent databases and smart tools for searching these databases and using the knowledge contained in them are another means for **reducing search costs in the market for technology.**”*

– Arora et al. (2001)