1 financial development, innovation intensity and trade

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1.1 related papers

three strands:

1)finance and innovation

Acemoglu and Zilibotti1997; Chakraborty and Ray2006,2007; Levine2002,2005; Holmstrom and Tirole1997; Aghion Benerjee and Piketty1999; Klette and Kortum2004; Wright2011; Sannikov2015,2016

2)finance and trade:

Costinot2009, Costinot and Vogel2010; Grossman and Rossi-hansberg2008, Ju and Wei2011, Manova2013, 2015,2016; Feenstra2014; IER2016

3)innovation and trade

Grossman and Helpman 1990,1991,1993;Aghion and Howitt1998,2009; Eaton and Kortum2001; Atkeson 2010; Baldwin2008

1.2 essential tradeoff

direct finance vs indirect finance

direct finance promotes competition, and provide various choices

indirect finance holds better monitoring technology, which alleviate moral hazard problem

1.3 model settings

Aghion Benerjee and Piketty1999

First we set up a Schumpeterian model without financial constraints. individuals live for two periods instead of one. In the first period of life an individual works in the final-good sector. In the second period she may become an entrepreneur and/or an intermediate monopolist, and if she becomes an entrepreneur she may use the wage earned in the first period to finance research.

The economy has a fixed population L, which we normalize to unity. Everyone is endowed with one unit of labor services in the first period and none in the second, and is risk neutral. There is one final good, produced under perfect competition by labor and a continuum of intermediate inputs according to

$$Y_t = L^{1-\alpha} \int_0^1 A_{it}^{1-\alpha} x_{it}^{\alpha} di, \ 0 < \alpha < 1$$

latest version of intermediate good i: x_{it}, technology associated with it:A_{it}

The final good is used for consumption, as an input to R&D, and also as an input to the production of intermediate products. At any date t, one old person in each intermediate sector i has an opportunity to innovate in that sector. If successful, she will become the monopolist in sector i for period t; if not, the monopoly will pass to another old person at random.

we suppose now that the starting technology in any given sector i at date t does not have the productivity parameter $A_{i,t-1}$ of that sector last period; instead it has the average $A_{t-1} = \int_0^1 A_{i,t-1} di$ across all sectors last period. So an entrepreneur that succeeds in innovating will have the productivity parameter $A_{i,t} = \gamma(i) A_{t-1}$, where $\gamma(i) > 1$ is the size of innovations, while the monopolist in a non-innovating sector will have $A_{i,t} = A_{t-1}$.

following Klette and Kortum2004

here, $\gamma(i)$ is a strictly increasing function, a higher index i industry has higher technology gap.

let $\mu(i)$ be the probability that an innovation occurs in any sector i at time t.

$$A_t = \int_0^1 [\mu(i)\gamma(i) + (1-\mu(i))]di \cdot A_{t-1}$$

growth rate

$$g = \frac{A_t - A_{t-1}}{A_{t-1}} = \int_0^1 [(\gamma(i)-1)\mu(i)]di$$

In each intermediate sector where an innovation has just occurred, the monopolist is able to produce any amount of the intermediate good one for one with the final good as input. Her price will be the marginal product of her intermediate good:

$$p_{it} = \alpha A_{it}^{1-\alpha} x_{it}^{\alpha-1}$$

profit maximization by the intermediate-good producer in sector i yields the equilibrium profit

$$\Pi_{it} = (1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}} A_{it}$$

gross output is

$$Y_t = \alpha^{\frac{2\alpha}{1-\alpha}} A_t$$

1.4 benchmark: innovation and growth without credit constraint

innovation technology

$$\mu(i) = \lambda(R_t(i)/A_t^*)^{1/2},\ \lambda > 0$$

where $R_t(i)$ is the amount of final good spent on R&D in a given sector at time t and $A_t^* = \gamma(i)A_{t-1}$ is the target productivity level.

three characteristics:

1) convex function: diminishing return

2) technology-adjusted: more advanced technology requires more R&D expenditure

3) positive parameter λ

It follows that the R&D cost of innovating with probability $\mu(i)$ is equal to

$$R_t(i) = A_t^* \mu^2(i)/\lambda^2$$

The entrepreneur will again choose the research expenditure $R_t(i)$ so as to maximize her expected payoff. choosing $R_t(i)$ is equivalent to choosing the innovation probability $\mu(i)$:

$$\max_{\mu(i)} \mu(i)(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}} A_t^* - A_t^* \mu^2(i)/\lambda^2$$

the equilibrium probability of innovation is

$$\mu(i) = \mu = \frac{(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}}\lambda^2}{2}$$

note that, without financial frictions, the equilibrium innovation intensity in each sector is the same, no matter what the technology gap is.

the equilibrium growth rate is

$$g = \frac{(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}}\lambda^2}{2}[\int_0^1 \gamma(i)di - 1]$$

1.5 moral hazard and optimal financing structure

following Holmstrom and Tirole1997, Chakraborty and Ray2006, introduce moral hazard problem:

investing $R_t(i)$ into R&D,

project	good	bad(low private benefit)	bad (high)
private benefit	0	$bR_t(i)$	$BR_t(i)$
prob of success	$\mu(i)$	$(1-\theta)\mu(i)$	$(1-\theta)\mu(i)$

where $1 > B > b > 0$ and $0 < \theta < 1$

we assume that

$$\mu(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}}A_t^* > (1-\theta)\mu(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}}A_t^* + BR_t$$

i.e.,

$$2\theta > B$$

where μ is the equilibrium innovation intensity as before

so, moral hazard problem is not social optimal.

intermediary monitoring cost (private and not verifiable): $cR_t(i)$

monitoring cost is less than its gain:

$$B > b + c$$

we also impose conditions on parameters:

$$\frac{\theta}{\theta - B} < (1-\alpha)^2 < \frac{\theta - (1-\theta)c}{\theta - (b + c\theta)}$$

the first one guarantee direct finance only will always left some sectors credit constrained; the second one guarantee the dominance of direct+indirect finace

1.5.1 direct finance only

one optimal contract: i) entrepreneur invest w_{t-1}, investors $R_t(i) - w_{t-1}$

ii) fails then nothing

iii) succeed: innovator and investor share:

$$D_f + D_u = (1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}}A_t^*$$

innovator choose good action if and only if incentive compatibility constraint holds:

$$\mu(i)D_f \geq (1-\theta)\mu(i)D_f + BR_t(i)$$

i.e.,

$$D_f \geq BR_t(i)/\theta\mu(i)$$

investor's share at most: $D_u = (1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}}A_t^* - BR_t(i)/\theta\mu(i)$

pledgeable expected income: $\mu(i)(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}}A_t^* - BR_t(i)/\theta$

investors put their money in sector i if and only if the expected return exceed opportunity cost:

$$\mu(i)(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}}A_t^* - BR_t(i)/\theta \geq R_t(i) - w_{t-1}$$

here, we do not introduce time preference, so discount rate is exactly one

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note that

$$R_t(i) = A_t^*\mu^2(i)/\lambda^2$$

and wage is given by

$$w_{t-1} = (1-\alpha)\alpha^{\frac{2\alpha}{1-\alpha}}A_{t-1}$$

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then, innovator's profit maximization problem (conditional on choosing good action) is

$$\max_{\mu(i),D_f} \mu(i)D_f - w_{t-1}$$

s.t.

$$D_f \geq BR_t(i)/\theta\mu(i)$$

$$\mu(i)((1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}}A_t^* - D_f) \geq R_t(i) - w_{t-1}$$

we suppose the second constraint always binds, since investors compete with each other to provide funding for innovators. then in equilibrium, investors are indifferent between investment and consumption.

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this requires that the total R&D expenditure in this period should not exceed the labor income of last period:

$$\int_1^0 R_t(i)di \leq w_{t-1}$$

note that, this condition is also needed in the benchmark model.

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so there are always excess supply of credit, which contributes to the equivalence of investor's choice between investment and consumption.

substitute into the profit function and IC constraint, we can restate the problem as

$$\max_{\mu(i)} \mu(i)(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}}A_t^* - R_t(i)$$

s.t.

$$\mu(i)(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}}A_t^* - R_t(i) \geq \frac{B}{\theta}R_t(i) + w_{t-1}$$

note that the unconstrained problem has solution that

$$\mu(i) = \mu = \frac{(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}}\lambda^2}{2}$$

no matter the value of $\gamma(i)$

so if the constrain is not bind, innovation intensity is also μ

now lets see when this condition is not bind, i.e.,

$$\mu(i)(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}}A_t^* - R_t(i) > \frac{B}{\theta}R_t(i) + w_{t-1}$$

we derive

$$\gamma(i) > \frac{4\theta}{(\theta - B)\lambda^2(1-\alpha)\alpha^{2/(1-\alpha)}}$$

since $\gamma(i)$ is strictly increasing, denote

$$\tilde{\imath} = \gamma^{-1}\left(\frac{4\theta}{(\theta - B)\lambda^2(1-\alpha)\alpha^{2/(1-\alpha)}}\right)$$

on the other hand, when entrepreneur can fund herself, she always take optimal innovation:

$$R_t(i) \leq w_{t-1}$$

i.e.,

$$\gamma(i) \leq \frac{4(1-\alpha)}{\lambda^2\alpha^{2/(1-\alpha)}}$$

since $\gamma(i)$ is strictly increasing, denote

$$\underline{i} = \gamma^{-1}\left(\frac{4(1-\alpha)}{\lambda^2\alpha^{2/(1-\alpha)}}\right)$$

utilize parameter condition

$$\frac{\theta}{\theta - B} < (1-\alpha)^2$$

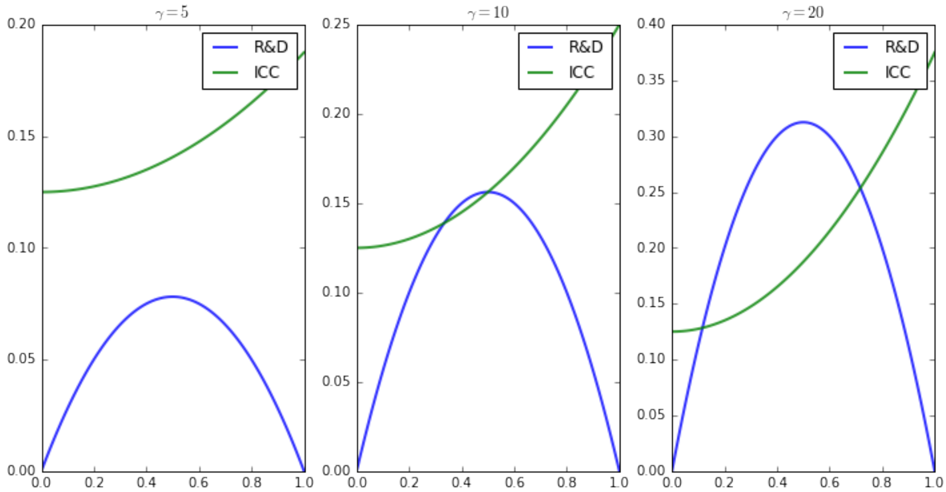
then $\underline{i} < \tilde{i}$

for sector $i \in [\underline{i}, \tilde{i}]$, condition is bind, and innovation intensity is a function of $\gamma(i)$, which satisfies the equation:

$$\frac{B+\theta}{\theta}\frac{\gamma(i)}{\lambda^2}\mu^2(i) - (1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}}\gamma(i)\mu(i) + (1-\alpha)\alpha^{\frac{2\alpha}{1-\alpha}} = 0$$

[note20160722

the problem is, ICC might always greater than RND, see plots below]



i.e.,

$$\mu(i) = \frac{\theta\lambda^2(1-\alpha)\alpha^{\alpha/(1-\alpha)}}{2(B+\theta)\gamma(i)}\left[\alpha^{1/(1-\alpha)}\gamma(i) + \sqrt{\alpha^{2/(1-\alpha)}\gamma^2(i) - \frac{4(B+\theta)}{\theta(1-\alpha)}\frac{\gamma(i)}{\lambda^2}}\right] < \mu = \frac{\alpha^{\frac{1+\alpha}{1-\alpha}}\lambda^2}{2}$$

we drop another root because of the profit maximization motive of R&D

so we have

$$\mu(i) = \begin{cases} \frac{\alpha^{\frac{1+\alpha}{1-\alpha}}\lambda^2}{2} & i \in [0, \underline{i}] \\ \frac{\theta\lambda^2(1-\alpha)\alpha^{\alpha/(1-\alpha)}}{2(B+\theta)\gamma(i)}\left[\alpha^{1/(1-\alpha)}\gamma(i) + \sqrt{\alpha^{2/(1-\alpha)}\gamma^2(i) - \frac{4(B+\theta)}{\theta(1-\alpha)}\frac{\gamma(i)}{\lambda^2}}\right] & i \in [\underline{i}, \tilde{i}] \\ \frac{\alpha^{\frac{1+\alpha}{1-\alpha}}\lambda^2}{2} & i \in [\tilde{i}, 1] \end{cases}$$

1.5.2 direct finance and indirect finance

optimal contract:

$$D_f + D_u + D_m = (1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}}A_t^*$$

as before IC for innovator to take good action

$$D_f \geq bR_t(i)/\theta\mu(i)$$

IC for intermediary to monitor

$$D_m \geq cR_t(i)/\theta\mu(i)$$

pledgeable expected income

$$\mu(i)[(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}}A_t^* - (b+c)R_t(i)/\theta\mu(i)]$$

R&D input

$$I_u + I_m^r + w_{t-1} = R_t(i)$$

uninformed investors put money in sector i if and only if the expected return exceed opportunity cost:

$$\mu(i)[(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}} A_t^* - (b+c)R_t(i)/\theta\mu(i)] \geq R_t(i) - I_m^r - w_{t-1}$$

define rate of return on intermediary capital:

$$r_m(i) = \mu(i)D_m/I_m$$

then required investment of intermediary is

$$I_m^r = cR_t(i)/\theta r_m(i)$$

determination of r_m: in a competitive equilibrium, banking sector earns zero profits so the expected return of monitoring must equal the opportunity cost of money

$$cR_t(i)/\theta - cR_t(i) = I_m^r = cR_t(i)/\theta r_m(i)$$

which yield

$$r_m = \frac{1}{1-\theta} > 1$$

substitute into uninformed investor's condition

$$\mu(i)(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}} A_t^* - \mu(i)D_f - cR_t(i)/\theta \geq R_t(i) - \frac{1-\theta}{\theta}cR_t(i) - w_{t-1}$$

which reduces into

$$\mu(i)(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}} A_t^* - \mu(i)D_f \geq R_t(i) + cR_t(i) - w_{t-1}$$

this condition always binds, so

$$\mu(i)D_f - w_{t-1} = \mu(i)(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}} A_t^* - (1+c)R_t(i)$$

profit maximization of R&D activity the problem is

$$\max_{\mu(i)} \mu(i)(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}} A_t^* - (1+c)R_t(i)$$

s.t.

$$\mu(i)(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}} A_t^* - (1+c)R_t(i) \geq bR_t(i) - w_{t-1}$$

compared with the case of direct finance only,

$$\max_{\mu(i)} \mu(i)(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}} A_t^* - R_t(i)$$

$$\mu(i)(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}} A_t^* - R_t(i) \geq BR_t(i)/\theta - w_{t-1}$$

the profit maximization problem is different in two aspects:
1) R&D cost is raised by additional monitoring cost
2) however, the constraint is looser, since when $B > b + c$ and $\theta < 1$,

$$B > b + c\theta$$

note that, innovators can always choose direct finance only
and since $\forall\mu(i)$

$$\mu(i)(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}} A_t^* - R_t(i)\mu(i) > (1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}} A_t^* - (1+c)R_t(i)$$

only those under credit constraint in "direct finance only" regime will choose direct+indirect finance

the direct+indirect case will impose looser constraints than the direct only case, which yield new threshold:

$$\tilde{\iota}' = \gamma^{-1}\left(\frac{4\theta}{(\theta-(b+c\theta))\lambda^2(1-\alpha)\alpha^{2/(1-\alpha)}}\right) < \tilde{\iota} = \gamma^{-1}\left(\frac{4\theta}{(\theta-B)\lambda^2(1-\alpha)\alpha^{2/(1-\alpha)}}\right)$$

that is, more sectors are now away from credit constraints, which result in optimal R&D decisions

from parameter restrictions we know that

$$\frac{\theta}{\theta-(b+c\theta)} > \frac{\theta-(1-\theta)c}{\theta-(b+c\theta)} > (1-\alpha)^2$$

then

$$\tilde{\iota}' < \underline{i}$$

credit constraints disappear in all sectors, but social efficiency is second-best.

1.5.3 indirect finance only

now, let's consider the opposite situation where there is only indirect finance available

consumers can either: i) save money in bank; and/or ii) for consumption

innovators can either: i) use their own money for R&D; and/or ii) borrow money from bank

bank is the only market maker of credit, and no direct finance is available

i.e., consumers are forbidden to lend money directly to innovators

optimal contract:

$$D_f + D_m = (1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}} A_t^*$$

IC for innovator to take good action

$$D_f \geq bR_t(i)/\theta\mu(i)$$

IC for intermediary to monitor

$$D_m \geq cR_t(i)/\theta\mu(i)$$

then there exists a threshold, below which intermediary will not monitor

$$I_m + w_{t-1} \geq R_t(i)$$

the rate of return of intermediary is also

$$r_m = \frac{1}{1-\theta}$$

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again, this rate is guaranteed by the perfect competition of bank sector, which yield zero profit.

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then intermediary are willing to invest

$$I_m = \frac{1-\theta}{\theta} cR_t(i)$$

substitute into the R&D expenditure, we derive a condition for $\gamma(i)$:

$$\gamma(i) \geq \frac{4(1-\alpha)}{\lambda^2\alpha^{2/(1-\alpha)}(1-\dfrac{1-\theta}{\theta}c)}$$

define

$$\tilde{\imath}'' = \gamma^{-1}\left(\frac{4(1-\alpha)}{\lambda^2\alpha^{2/(1-\alpha)}(1-\dfrac{1-\theta}{\theta}c)}\right)$$

note that

$$\underline{i} = \gamma^{-1}\left(\frac{4(1-\alpha)}{\lambda^2\alpha^{2/(1-\alpha)}}\right) < \tilde{\imath}'' = \gamma^{-1}\left(\frac{4(1-\alpha)}{\lambda^2\alpha^{2/(1-\alpha)}(1-\dfrac{1-\theta}{\theta}c)}\right)$$

then sectors in $[\underline{i}, \tilde{\imath}'']$ are subject to credit constraints
direct+indirect finance dominate indirect finance only, $\tilde{\imath}' < \tilde{\imath}''$ if and only if

$$\frac{\theta-(1-\theta)c}{\theta-(b+c\theta)} > (1-\alpha)^2$$

which is imposed in the parameter assumption

1.6 comparing three regimes

PROPOSITION 1 (OPTIMALITY OF DIRECT+INDIRECT FINANCE) under parameter restrictions:

i) $2\theta > B > b+c$

ii) $\dfrac{\theta}{\theta-B} < (1-\alpha)^2 < \dfrac{\theta-(1-\theta)c}{\theta-(b+c\theta)}$

we have:

i) direct finance only and indirect finance only are both dominated by direct+indirect finance regime

ii) moreover, the direct+indirect finance regime achieves no credit friction output in the benchmark

1.7 open economy

now, lets consider an open economy with two countries North and South

north have optimal finance structure, will south do not

but this is the only difference between these tow countries.

for simplicity, we abstract trade barriers, and the new world economy reduces into an integrated equilibrium with two type of agents:

those with (potential) credit constraint and those without it

each country have measure 1/2 potential innovators, uniformly distributed in sector $[0,1]$

one more plausible assumptions:

without credit constraint, people are always glad to innovate in high index sectors

1.7.1 perfect south

then north and south are the same ex ante , both hold measure 1/2 of $[0,1]$ as leading sectors ex post, and trade with each other

the average export product index of south (and north) are

$$I_s = 2\int_0^1 \chi_{\{s\ lead\ in\ i\}} idi = 2\int_0^1 \frac{\frac{1}{2}}{\frac{1}{2}+\frac{1}{2}} idi = \frac{1}{2} = I_n$$

the world economy is at a fair and balanced growth path

1.7.2 imperfect south

since direct only and indirect only both result in some sectors under credit constraints, we only consider the direct only case

we denote south sectors $[\underline{i}, \tilde{\imath}]$ as those which are subject to credit constraints and cannot compete with their north counterpart

1) sectors in $[\tilde{\imath}, 1]$

these sectors will be divided equally into south and north

so south and north both have measure $\frac{1}{2}(1-\tilde{\imath})$ of sectors

2) sectors in $[\underline{i}, \tilde{\imath}]$

two situations:

i) $\tilde{\imath} - \underline{i} \leq \frac{1}{2} - \frac{1}{2}(1-\tilde{\imath}) = \frac{1}{2}\tilde{\imath}$

then north will take all sectors in $[\underline{i}, \tilde{\imath}]$ with measure $\tilde{\imath} - \underline{i}$

for sector in $[0, \underline{i}]$, north will take measure $\underline{i} - \frac{1}{2}\tilde{\imath}$

south will take the rest

sector	world	south	north
$[0,1]$	1	1/2	1/2
$[\tilde{\imath}, 1]$	$1-\tilde{\imath}$	$\frac{1}{2}(1-\tilde{\imath})$	$\frac{1}{2}(1-\tilde{\imath})$
$[\underline{i}, \tilde{\imath}]$	$\tilde{\imath} - \underline{i}$	0	$\tilde{\imath} - \underline{i}$
$[0, \underline{i}]$	$\underline{i}$	$\frac{1}{2}\tilde{\imath}$	$\underline{i} - \frac{1}{2}\tilde{\imath}$

$$I_s = 2\int_0^1 \chi_{\{s\ lead\ in\ i\}} i di = 2\left(\int_0^{\underline{i}} \frac{\frac{1}{2}\tilde{\imath}}{\underline{i}} i di + \int_{\tilde{\imath}}^1 \frac{\frac{1}{2}(1-\tilde{\imath})}{1-\tilde{\imath}} i di\right) = \frac{1}{2}(1-\tilde{\imath}^2 + \underline{i}\tilde{\imath}) < \frac{1}{2}$$

$$I_n = 2\int_0^1 \chi_{\{n\ lead\ in\ i\}} i di = \frac{1}{2}(1+\tilde{\imath}^2 - \underline{i}\tilde{\imath}) > \frac{1}{2}$$

the world economy is at optimal allocation, but trade and income distribution is biased to north

ii) $\tilde{\imath} - \underline{i} > \frac{1}{2}\tilde{\imath}$

then north will only take sector in $[\frac{1}{2}\tilde{\imath}, \tilde{\imath}]$

while south innovator will take $[\underline{i}, \frac{1}{2}\tilde{\imath}]$ inefficiently, because they are facing credit constraints

sector	world	south	north
$[0,1]$	1	1/2	1/2
$[\tilde{\imath}, 1]$	$1-\tilde{\imath}$	$\frac{1}{2}(1-\tilde{\imath})$	$\frac{1}{2}(1-\tilde{\imath})$
$[\underline{i}, \tilde{\imath}]$	$\tilde{\imath} - \underline{i}$	$\frac{1}{2}\tilde{\imath} - \underline{i}$ of $[\underline{i}, \frac{1}{2}\tilde{\imath}]$, inefficiently	$\frac{1}{2}\tilde{\imath}$ of of $[\frac{1}{2}\tilde{\imath}, \tilde{\imath}]$
$[0, \underline{i}]$	$\underline{i}$	$\underline{i}$	0

$$I_s = \frac{1}{2}(1 - \frac{1}{2}\tilde{\imath}^2) < \frac{1}{2}$$

$$I_n = \frac{1}{2}(1 + \frac{1}{2}\tilde{\imath}^2) > \frac{1}{2}$$

because south inefficient innovator, the world economy is no longer at optimal allocation

while trade and income distribution is still biased to north

1.8 finance, innovation and trade

PROPOSITION 2 (FINANCIAL FRICTION AND TRADE PATTERNS) financial frictions make trade and income distribution biased north. more frictions increase north export technology index, decrease south export technology index.

moreover, there exists a threshold below which, frictions would results in inefficient outcomes.