Financial Frictions, Innovation, and Economic Growth*

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Abstract

The generation and implementation of new ideas, or knowledge, is a major factor underlying economic growth. It is commonly believed that financial development plays a role in facilitating this process. We analyze these issues by building an endogenous growth model where advances in knowledge lead to increases in productivity, and this is aided by the exchange of ideas, but credit frictions can impede this market and hence hinder the advancement of knowledge and economic growth. Knowledge here is a nonrival goods at least in the long run, as ideas enter the public domain. We also present evidence for the case that technology transfers are an important part of the innovation process, and that credit market imperfections hinder this process.

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1 Introduction

It is commonly understood that the generation and implementation of new ideas and technologies – or, the development of knowledge – is a major factor underlying economic performance and growth. Versions of this position go back at least to Schumpeter. It is also commonly understood that financial development plays a role in facilitating this process, as discussed e.g. in the survey by Levine (2004). This project is an attempt to better understand these issues.

To this end, we build an endogenous 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, but also come up with ideas for innovations that increase their own knowledge and productivity z. Increases in z increase individual profits, in the short run, while in the longer run the knowledge enters the public domain and can be used by everyone. In the simplest setting, an individual innovator i who comes up with an idea tries to develop it on his or her own, and only succeed with probability λ_i, which is itself random. One can think of λ_i as indexing the quality of the idea, although we actually prefer to think of it as indexing the match between an idea and the individual's expertise – some people are just better than others at developing certain ideas. In our benchmark model, although the probability of successful innovation is random, each success advances the frontier by some deterministic amount η (it is not hard to also make η random).

An individual producer's own knowledge z, which may be beyond the frontier knowledge Z, determines his own productivity in the short run. But as we said, after he puts it to use, others can see and absorb the knowledge. In this way, the public domain frontier Z evolves over time. We adopt a simple but flexible aggregator for this evolution, allowing for the frontier next period to be a function of the entire profile of knowledge in the hands of individuals today. Thus, $Z' = \rho \left[\int_0^1 z_i^{\varepsilon} di\right]^{1/\varepsilon}$, where ρ is an exogenous component, and ε affects the degree of substitution between individual innovations in producing aggregate knowledge. As special cases, before adjusting for the exogenous component, baseline productivity next period may be given by average productivity this period, by the maximum or minimum (we all stand on the shoulders of the individual with the best knowledge, or we can be dragged down by the one with the worst), and so on.

Given standard preference conditions, the model generates a balanced growth path. That is, in competitive equilibrium output, consumption, wages, asset prices, and profit all grow at the same rate as knowledge Z, while employment hours are constant. There is no physical capital in the benchmark model, although we do include real assets in fixed supply that generate dividends, as these will be useful in some applications. In fact it is easy to get closed-form solutions for simple specifications of the production function $f(h)$. The growth rate depends endogenously on the expected number of successful innovations by individuals $N = \mathbb{E}_i \lambda_i$, the distance by which these move individual knowledge η, and the elasticity parameter ε in the law of motion for aggregate knowledge, as well as the exogenous component ρ. This model, however, is only a building block.

We want to move beyond the case where individual producers all try to implement their own ideas, and analyze a phenomenon referred to in the literature as *technology transfer*. This concerns the following issue: When innovators generate new ideas, should they try to develop and implement them themselves? Or should they try to sell their ideas to others, let us say to entrepreneurs, who may be better at implementation? If agents are heterogeneous in the ability to come up with ideas and to extract their returns, it makes sense for some to specialize in innovation and others in implementation. It is commonly understood in this literature that the transfer of ideas from innovators to entrepreneurs can lead to a more efficient use of resources, making all parties better off and increasing incentives for investment in innovation.

For example, as Katz and Shapiro (1986) put it, "Inventor-founded startups are often second-best, as innovators do not have the entrepreneurial skills to commercialize new ideas or products." Further, a special feature in The Economist (2005) on the market for ideas, patents, and related topics notes that "as the patent system has evolved, it ... leads to a degree of specialization that makes business more efficient. Patents are transferable assets, and by the early 20th century they had made it possible to *separate the person who makes an invention from the one who commercializes it*. This recognized the fact that *someone who is good at coming up with ideas is not necessarily the best person to bring these ideas to market*" (emphasis added). We want to study technology transfer in the context of endogenous growth theory.[1]

Given our focus on direct technology transfer, we need to set up a market for this to happen. We choose to model this market as one in which various frictions may play a role. First, we have innovators and producers match bilaterally and at random, as in standard search theory. We think this captures in a reasonable, if extreme, way the notion that the exchange of information is relatively

[1] Technology transfers are not the only mechanism for the exchange of ideas, and there are many ways for innovators and entrepreneurs to interact. Often this involves longer-term partnerships, as e.g. in the venture capital market (Gompers and Lerner 1999). Our focus is on situations where an innovator wants to sell his idea outright, rather than enter into a joint venture. As the literature emphasizes, direct technology transfer is a significant part, if not the biggest part, of the market for ideas. One advantage of direct technology transfer is that it avoids strategic incentive problems with joint implementation. Another is that it allows innovators to get "back to the drawing board" in an effort to come up with even more new ideas, which is their specialty, rather than getting tied up with implementation. In any case, it is not that we think other ways to implement new ideas are without interest; it is just that we choose to focus on direct technology transfers in this study.

decentralized, and it is not straightforward either to find someone who has an idea that you might be good at implementing, or to find someone who may be good at implementing your idea. Second, given bilateral meetings, it is natural to allow the terms of trade in the idea market to be determined by bargaining, rather than Walrasian price taking. Third, we want to consider the possibility that the ability of entrepreneurs to pay innovators up front for their ideas may be important. This brings us into the interesting realm of liquidity, and allow us to study how financial development impinges on technology transfers, and hence on growth.[2]

To motivate our focus on liquidity, note that credit may be difficult in this market because, among other reasons, ideas are difficult to collateralize: if I tell you something in exchange for a promise of future payment, and then you fail to pay, it can be hard to repossess the information. Of course this depends on the extent of intellectual property rights, including patent protection, the ease of verifying information to third parties, etc., which we want to discuss. Also, even if innovators and entrepreneurs can form partnerships or other joint ventures to ameliorate credit frictions, this raises a host of new problems, including those associated with opportunistic behavior due to informational problems and hold up problems. The first principle in Contract Theory 101 is that the first best can be achieved if I simply sell you my idea, since this internalizes all of the relevant incentive problems. Why this may not happen has always been a delicate question for Contract Theory, often dismissed someone cavalierly with the answer "liquidity constraints." We want to take this relatively seriously, and make liquidity endogenous. Then we wan to embed our frictional idea market, with potential difficulties involving matching, bargaining, and liquidity, into the

[2] Notice that this is not a model where entrepreneurs have an idea and need money to start a business. Our entrepreneurs have money, but need an idea, which they can try to buy from an innovator.

competitive growth model.[3]

Before proceeding, we want to clarify why the objects being traded are ideas, as opposed to some generic factor of production. First, ideas are indeed inputs here, but they are inputs into the expansion of knowledge where knowledge then impacts on productivity. Second, our ideas are indivisible – either I tell you or I don't – although this is more of a technical than a fundamental economic property of ideas. Third, we allow ideas to be nonrival goods – if I tell you my idea I may still be able to use it – even in the short run, and certainly in the long run when knowledge enters the public domain. Fourth, as we said, ideas are difficult to collateralize, making credit problematic and motivating the consideration of liquidity. Fifth, the idea market is rife with information problems, including adverse selection (how do you know my idea is any good) and moral hazard (how do you know I will carry my weight if we work on it together), motivating a general desire to transfer ideas directly rather than trying to implement them as joint ventures.

The rest of the paper is organized as follows. In Section 2 we present the growth model without technology transfers, where individual innovators try to implement new ideas for themselves. In Section 3 we introduce a new set of agents, called entrepreneurs, who may be better at implementing ideas, generating gains from trade. We do not include credit frictions in this Section, so the idea market actually works fairly well, at least subject to the constraints

[3] This basic setup is somewhat reminiscent of the theory in Holmes and Schmitz (1990, 1995), who also assume ideas arrive randomly and individuals differ in their abilities to develop them, but they only study centralized competitive markets while we allow frictions to play a role. Many people have thought about credit frictions in innovation and entrepreneurship, generally, of course. Some, like Lloyd-Ellis and Bernhardt (2000) and Buera (2005), simply assume there is no credit. Others, like Evans and Jovanovic (1989) assume credit is exogenously limited to a fixed multiple of wealth. Others, like Aghion and Bolton (1996) and Fazzari et al. (1988, 2000), try to model credit frictions using private information. See Chatterjee and Rossi-Hansberg (2009) and Silveira and Wright (fothcoming) for recent economic analyses of the idea market and many more references. There is also a literature studying the relationship between inflation and growth (e.g., Gomme (1993) and Berentsen et al (2009)).

imposed by random matching and information. Still, when we endogenize the relative numbers of entrepreneurs and innovators, it is not clear the outcome is socially efficient. In Section 4 we introduce financial frictions with assumptions that make it impossible for entrepreneurs to pay for ideas on credit, which generates a role for liquidity.

In Section 5 we relax these extreme assumptions, so that credit may be more or less difficult, but is not necessarily impossible, which allows us to analyze how the development of the financial sector affects technology transfer and growth. In particular, we do two things: First, we allow entrepreneurs who are short of liquidity when they meet an innovator with a very good idea to try to raise additional funds, but this only works with some exogenous probability, as in Silveira and Wright (forthcoming). Second, we explicitly introduce financial intermediaries that agents may or make not access as an endogenous choice, as in Chiu and Meh (forthcoming). In Section 6 we present a little evidence trying to make the case that technology transfer can be an important part of the innovation process, and that credit market imperfections can hinder this process. Finally, Section 6 concludes.

2 The Basic Growth Model

Time is discrete and continues forever. There is a $[0, 1]$ continuum of infinite-lived households. Each period, a household solves

$$\begin{aligned} W(a, Z) &= \max_{c,h,a'} \{u(c) - \chi h + \beta W(a', Z')\} \\ \text{st } c &= wh + (\phi + \delta^a Z)a - \phi a' + \pi, \end{aligned} \tag{1}$$

where c is consumption, h labor supply, a asset holdings, Z the aggregate state of knowledge (productivity), w the wage, ϕ the asset price, δ^a a dividend on the asset, and π profit. One can think of assets as (claims to) "trees" in fixed supply

A, bearing "fruit" as dividends, as in standard asset-pricing theory. However, in our growth model, "fruit" is not a final consumption good, but an intermediate good that can be turned into c according to the linear technology $c = Z\delta^a a$. Thus, as productivity Z grows, it gets easier to turn dividends into consumption, and Z is the price of these intermediate goods in terms of the numeraire c.[4] Other than these assets in fixed supply, for simplicity, there is no additional physical capital in the benchmark model. These assets are included because they will be useful below in our discussion of liquidity and financial frictions.

Individual households can also be thought of as owners and operators of firms (although it is equivalent to have separate operator that simply pay back profits to the household owners). The profit maximization problem is

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

where H is labor demand and z is the individual firm's productivity. One can think of labor producing $f(H)$ units of the same intermediate good generated as the dividend of the asset, which can be turned into consumption according to $c = zf(H)$. However, an individual producer has its own value of z, which may differ from the aggregate Z. In particular, each period a producer starts with the aggregate state of knowledge Z, but then gets an idea for an innovation which increases individual productivity from $z = Z$ to $z = (1 + \eta)Z$ with probability λ.[5]

[4] Alternatively, one can think of the "fruit" as final consumption goods, but "trees" simply get more productive in terms of their yields with increases in Z. Although it does not matter for the results, for concreteness, in the text we present the model interpreting the dividend as an intermediate input, which is the same as the output of labor in the production function described below, all of which is turned into final consumption c according to a technology with productivity Z.

[5] Notice that this means that profit income π in the budget constraint in (1) is random, so one should think of the market as opening after individual productivity z is realized; but this does not matter, since given our quasi-linear specification households have no incentive to insure against this risk. If there were such an incentive we could easily allow them to hold a diversified portfolio of shares in other firms.

In this model, λ is random across producers, drawn from CDF $F_i(\lambda_i)$. Thus, individual productivity in a given production period is given by

$$z = \begin{cases} Z(1+\eta) & \text{with prob } \lambda \\ Z & \text{with prob } 1-\lambda \end{cases}$$

One can think of λ as capturing the quality of the idea, or as a measure of skill that any individual has at implementing a particular idea – maybe there are some ideas that are good in an abstract sense but not a good match for your expertise. This will motivate the generalized model below where agents may try to trade ideas. For now, this market is shut down, so agents simply try to implement their own ideas. Hence, The number of successful innovations is $N = \int_0^1 \lambda_i dF_i(\lambda_i) = \mathbb{E}_i \lambda_i$. Although the probability of success is random, each successful innovation in this benchmark model advances individual productivity by a deterministic amount η.[6]

The aggregate state of knowledge evolves from one period to the next according to

$$Z' = \rho \left[\int_0^1 z_i^{\varepsilon} di \right]^{1/\varepsilon} = \rho \left[N(1+\eta)^{\varepsilon} Z^{\varepsilon} + (1-N) Z^{\varepsilon} \right]^{1/\varepsilon}$$

where ρ is an exogenous component that augments or depreciates knowledge as ρ is above or below 1, and ε is a parameter affecting the substitutability of different individual innovations in generating aggregate knowledge. As special cases, before adjusting for ρ, baseline productivity next period may be given by average productivity this period if $\varepsilon = 1$, by the maximum if $\rho = +\infty$ (we all stand on the shoulders of the individual with the best knowledge last period), by the minimum if $\rho = -\infty$ (we can be dragged down by the one with the worst knowledge, as in an "O ring" model), and so on. In any case, the growth rate

[6] We also worked out the case where η is random, but other than increasing the notation it did not add much.

of productivity is

$$1+g=\frac{Z'}{Z}=\rho\left[N(1+\eta)^{\varepsilon}+1-N\right]^{1/\varepsilon}. \tag{2}$$

We seek a balanced growth equilibrium where c, w and ϕ grow at the same rate g as Z, while h is constant.

Eliminating h from the budget constraint and inserting π, we can rewrite the consolidated household/producer problem as

$$W(a,Z)=\max_{c,a',H}\left\{u(c)-\frac{\chi}{w}\left[c-(\phi+\delta^{a}Z)a+\phi a'\right]+\frac{\chi}{w}\mathbb{E}\left[zf(H)-wH\right]+\beta W(a',Z')\right\}.$$

Due to the linearity of the underlying objective function in h, this consolidated problem conveniently separates as

$$\begin{aligned} W(a,Z) \quad = \quad & \max_{c}\left\{u(c)-\frac{\chi}{w}c\right\}+\max_{a'}\left\{\beta W(a',Z')-\frac{\chi}{w}\phi a'\right\} \\ & +\frac{\chi}{w}(\phi+\delta^{a}Z)a+\frac{\chi}{w}\mathbb{E}\max_{H}\left\{zf(H)-wH\right\}, \end{aligned}$$

so that the choices of consumption c, investment a', and hiring H are independent. In terms of hours, notice that an individual can work for his own firm, but can in principle additionally work for other firms, when $h>H$.[7] The envelope condition implies that W is linear in a, with $W_a=\chi(\phi+\delta^{a}Z)/w$. The FOC are

$$\begin{aligned} c \quad &: \quad u'(c)=\frac{\chi}{w} \\ a' \quad &: \quad \frac{\chi}{w}\phi=\beta W_{a'}(a',Z') \\ H \quad &: \quad zf'(H)=w \end{aligned}$$

There are four goods and hence four markets here: There is a market for dividends, but we already know it clears at a price in terms of the numeraire Z.

[7] As we said before, π is random, since it depends on the success of the innovation effort, but since utility is quasi-linear there is no incentive to share such risk across agents.

There is a market for assets, but combining the envelope and FOC for a' we get

$$\frac{\chi}{w}\phi = \beta\frac{\chi}{w'}(\phi' + \delta^a Z'),$$

which, by balanced growth, clears iff $\phi = Z\delta^a\beta/(1-\beta)$. This says that ϕ must be at its *fundamental* price, the present value of the implied dividend stream (but see below where it may bear a liquidity premium). There are also markets for consumption goods and for labor, but by Walras' Law we only have to worry about one of these, and it turns out to be easier to focus on the former.

In terms of goods market supply, $S = S(w)$, we have

$$\begin{aligned} S &= \int_0^1 z_i f(H_i)di + A\delta^a Z \\ &= N(1+\eta)Zf(H_1) + (1-N)\,Zf(H_0) + A\delta^a Z \\ &= Z\left[N(1+\eta)f(H_1) + (1-N)\,f(H_0) + A\delta^a\right], \end{aligned}$$

where H_0 and H_1 solve the FOC's from profit maximization, $Z(1+\eta)f'(H_1) = w$ and $Zf'(H_0) = w$. Note that H_0 and H_1 depend only on w/Z. For a given Z, the supply curve $S = S(w)$ slopes downward (because we are considering quantity as a function of w, which is actually the inverse of the price of this good):

$$S'(w) = \frac{Nf'(H_1)}{f''(H_1)} + \frac{(1-N)f'(H_0)}{f''(H_0)} < 0.$$

Also, $S(w)$ shifts out with Z for a given w.

In terms of demand, which we write $D = D(w)$, the FOC indicates that all households choose the same consumption, the value of c satisfying $u'(c) = \chi/w$. In general, it is upward sloping (again because we are considering quantity as a function of w, which is the inverse of the price of the good):

$$D'(w) = \frac{-\chi}{w^2 u''(c)} > 0.$$

It is easy to verify that to get balanced growth we need $u(c) = \log(c)$.[8] Given this, the FOC implies $c = w/\chi$, which means demand in (c, w) space is linear through the origin. Notice that an increase in Z does not affect $D(w)$. Since it shifts out supply $S(w)$, so both c and w increase with an increase in Z by the same proportion along the linear demand curve.

Equating $S(w)$ and $D(w)$ leads to the goods market clearing condition

$$\frac{w}{\chi} = Z\left[N(1+\eta)f(H_1) + (1-N)\,f(H_0) + A\delta^a\right],$$

which is one equation in w/Z since, as we said above, H_1 and H_0 are functions only of w/Z. As an example, consider

$$f(H) = 1 - \exp(-H)$$

which satisfies the usual properties $f' > 0$ and $f'' < 0$, although it does not imply the Inada condition $f'(0) = \infty$ that people sometimes like to use. The FOC in this case is $f'(H) = \exp(-H) = w/z$, implying $f(H_1) = 1 - w/Z(1+\eta)$ and $f(H_0) = 1 - w/Z$. This implies supply is linear, $S(w) = Z\left[1 + N\eta + \delta^a A\right] - w$. Equating $S(w) = D(w)$ in this case, we can easily solve for

$$\frac{w}{Z} = \frac{\chi}{1+\chi}\left[1 + N\eta + A\delta^a\right]$$

where again $N = \mathbb{E}_i\lambda$. From this we easily get $c = w/\chi$, H_0, H_1 etc.

In this benchmark model, the economic growth rate given by equation (2) depends on both the implementation of new ideas, with the number of successes $N = \mathbb{E}_i\lambda_i$, and on technological parameters. For now, N is exogenously determined by the distribution of the quality of ideas or, as we would prefer to say,

[8] In general it is standard to show balanced growth requires either $U = \log(c) + v(h)$ or $U = c^\varsigma v(h)$ where $v(h)$ is an appropriate function. We need in the generalized model with liquidity considerations, for technical reasons, to work with the first case, and in fact we need $v(h) = -\chi h$ as specified in (1). Hence we need $u(c) = \log(c)$ for balanced growth in this model (or, at least, in the generalized versions with liquidity considerations).

the distribution of matches between the ideas and the skills of the individual innovators. As the average match between ideas and innovators' skills improves, the growth of knowledge improves, and productivity increases faster, leading to growth rates in wages, output and consumption. Improvement in the overall quality of ideas, captured by η, has similar effects. Obviously an increase in the parameter ρ will also increase the growth rate of the economy.[9] It would be simple to endogenize various aspects of this process, e.g. one could give producers a choice as to how much to invest in innovative activity, at some cost, leading to improvements in the λ_i distribution or increases in η. In this paper, however, we are less concerned with how the number or the quality of ideas is generated, and more concerned with the problem of trying to get the ideas into the hands of the right people – those who may have comparative advantage at implementing them.

3 Technology Transfer without Credit Frictions

We now introduce a new set of agents, called entrepreneurs, who may have comparative advantage in implementing certain ideas. Now the population is divided into innovators, denoted i, and entrepreneurs, denoted e. There are positive measures n_i and $n_e = 1 - n_i$ of each. Since entrepreneurs may be better at implementing some ideas, there may be gains from trade. In particular, given his skills, suppose that i has an idea that will succeed with probability λ_i draw from $F_i(\lambda_i)$. If we randomly match him with e, the latter will succeed with probability λ_e drawn from $F_e(\lambda_e|\lambda_i)$. We want innovators and entrepreneurs meet in a frictional market. Thus, in between meetings of the system of markets described above, we now introduce a decentralized market where entrepreneurs

[9] Notice that an increase in the stock of the asset or its dividend, δA, will increase the wage rate and consumption, but not the growth rate.

and innovators meet bilaterally and trade ideas.

At the beginning of each period, agents first learn the aggregate state of knowledge Z. Innovators then come up with new ideas, and are randomly matched with entrepreneurs in the decentralized market. In any given meeting, we assume for simplicity that i and e can both observe λ_i and λ_e. If they want to trade, they bargain over a price p that e pays i for the idea. After this, the owner implements the idea, which improves individual productivity from $z = Z$ to $z = Z(1+\eta)$ if it succeeds. Then all agents enter the markets where they work, produce, consume, and adjusting their portfolios as described in the previous section. For now we assume ideas are rival goods in the short run: if i gives his idea to e the latter can try to implement it while the former cannot. This is for ease of notation, however, and one can alternatively assume ideas are nonrival goods, so both can try to implement, even in the short run, as in Silveira and Wright (forthcoming), but in any case, as in the benchmark model, knowledge enters the public domain next period.

We need to modify slightly the problem of a type $k = i, e$ agent to account for the fact that there may be trade of ideas between rounds of trading in the other markets. Let $V^k(a, Z)$ be the value function for type k entering the idea market, before realization of the matching process. Then

$$\begin{aligned} W^k(a,Z) &= \max_c \left\{ u(c) - \frac{\chi}{w} c \right\} + \max_{a'} \left\{ \beta V^k(a', Z') - \frac{\chi}{w} \phi a' \right\} \\ &\quad + \frac{\chi}{w}(\phi + \delta^a Z) a + \frac{\chi}{w} \max_H \left\{ z f(H) - wH \right\}, \end{aligned}$$

which is similar to (1) except $V^k(a', Z')$ replaces $W^k(a', Z')$. Since $W^k(a, Z)$ is linear in wealth, with slope $\frac{\chi}{w}$, as in any quasi-linear model, the gain from the successful implementation of an idea is $\Delta = \frac{\chi}{w}(\pi_1 - \pi_0)$ where $\pi_1 = Z(1+\eta) f(H_1) - wH_1$ and $\pi_0 = Z f(H_0) - wH_0$. For example, when $f(H) = 1 - \exp(-H)$ we have

$$\Delta = \frac{\chi}{w} Z[\eta - \frac{w}{Z} \log(1+\eta)].$$

In the idea market, a potential trade meeting occurs for e with probability α_e, while with probability $1 - \alpha_e$, e either does not meet anyone, or meets someone but cannot trade because he does not have the expertise (or information) to evaluate the idea. In general, the number of potential trade matches is determined by an abstract matching function $\mu(n_i, n_e)$. For now we study the case in which e has *deep pockets*, and thus can always finance trade in the idea market. There is no liquidity problem. For example, e may have access to unlimited (within the relevant range) funds, or a credit line, or whatever. The exact details are not relevant here, so we simply assume e can perfectly transfer wealth to i in this market. The terms of trade are determined by generalized Nash bargaining, with θ the bargaining power of e. Given any λ_i and $\lambda_e > \lambda_i$ in a meeting, this means:

$$p = \arg\max \left[\lambda_e \frac{\chi}{w}(\pi_1 - \pi_0) - p\right]^{\theta} \left[p - \lambda_i \frac{\chi}{w}(\pi_1 - \pi_0)\right]^{1-\theta}$$

The solution (see Figure 1) is easily determined to be:

$$p(\lambda_e, \lambda_i) = \frac{\chi}{w}(\pi_1 - \pi_0)[\theta\lambda_i + (1-\theta)\lambda_e]$$

The value function for e is then

$$\begin{aligned} V^e(a,Z) &= \alpha_e \int_0^1 \int_{\lambda_i}^1 \left[W_0^e(a,Z) + \theta \frac{\chi}{w}(\pi_1 - \pi_0)(\lambda_e - \lambda_i)\right] dF_e(\lambda_e|\lambda_i) dF_i(\lambda_i) \\ &\quad + \alpha_e \int_0^1 W_0^e(a,Z) F_e(\lambda_i|\lambda_i) dF_i(\lambda_i) + (1-\alpha_e) W_0^e(a,Z). \end{aligned}$$

The three terms correspond to the events where e meets i with lower λ, where e meets i with higher λ, and where e meets no one. Simplifying, we have

$$V^e(a,Z) = W_0^e(a,Z) + \alpha_e \theta \frac{\chi}{w}(\pi_1 - \pi_0)\hat{\mathbb{E}}(\lambda_e - \lambda_i),$$

where

$$\hat{\mathbb{E}}(\lambda_e-\lambda_i) = \mathbb{E}(\lambda_e-\lambda_i|\lambda_e > \lambda_i)\Pr(\lambda_e > \lambda_i) = \int_0^1 \int_{\lambda_i}^1 (\lambda_e-\lambda_i) dF_e(\lambda_e|\lambda_i) dF_i(\lambda_i).$$

Similarly,

$$V^i(a,Z) = W_0^i(a,Z) + \lambda_i \frac{\chi}{w}(\pi_1 - \pi_0) + \alpha_i(1-\theta)\frac{\chi}{w}(\pi_1 - \pi_0)\hat{\mathbb{E}}(\lambda_e - \lambda_i).$$

Note that all none of the equilibrium conditions in the benchmark model change. The only difference is that now the number of successfully implemented ideas is given by

$$N = n_i \mathbb{E}\lambda_i + n_e \alpha_e \hat{\mathbb{E}}(\lambda_e - \lambda_i).$$

The first term is the number of success when all ideas are implemented by innovators, as in the benchmark, since here n_i ideas each succeed with probability λ_i. The second term captures the additional successes when ideas are traded in matches where e has a comparative advantage and implemented with skill λ_e instead of λ_i. The equilibrium growth rate is still

$$1 + g = \rho \left[N \left(1 + \eta\right)^{\varepsilon} + 1 - N \right]^{\frac{1}{\varepsilon}},$$

although of course N is different. Growth depends on, in addition to parameters ρ, η and ε, the market outcome N, which in turn depends on the measures n_i and n_e, the distributions F_i and F_e, and the matching rates α_i and α_e. Growth is however independent of the bargaining weight θ and the supply of assets δA.

It is easy to work out parametric examples. Returning to the case $f(H) = 1 - \exp(-H)$, now also suppose that all entrepreneurs have $\lambda_e = 1$ with probability 1, while the match between innovators' ideas and skills come from a uniform distribution, $F_i(\lambda_i) = \lambda_i$. If the number of matches be determined by a CRS matching technology $\mu(n_i, n_e)$, then it is simple to see that the equilibrium growth rate is given by:

(i) When $\varepsilon = 1$, $1 + g = \rho \left\{1 + \frac{1}{2}\eta[n_i + \mu(n_i, 1 - n_i)]\right\}$.

(ii) When $\varepsilon = \infty$, $1 + g = \rho(1 + \eta)$.

(iii) When $\varepsilon = -\infty$, $1 + g = \rho$.

Before moving on to discuss imperfect credit, consider endogenizing the number of entrepreneurs entering the idea market. Suppose e has to pay cost κ to enter this market. Then, free entry equates this cost and the expected gain from trade,

$$\kappa = \alpha_e \theta \frac{\chi}{w}(\pi_1 - \pi_0)\hat{\mathbb{E}}(\lambda_e - \lambda_i).$$

Suppose $f(H) = 1 - \exp(-H)$, and the number of matches is given by $\mu(n_i, n_e)$. Then this simplifies to

$$\kappa = \frac{\mu(n_i, n_e)}{n_e}\theta\chi[\frac{\eta}{\bar{w}} - \log(1 + \eta)]\hat{\mathbb{E}}(\lambda_e - \lambda_i), \tag{3}$$

which implies a negative relationship between n_e and $\bar{w} = w/Z$. Also, as above, goods market clearing implies

$$\bar{w} = \frac{\chi}{1 + \chi}\left[1 + N\eta + A\delta^a\right] \tag{4}$$

with $N = n_i\mathbb{E}\lambda_i + \mu(n_i, n_e)\hat{\mathbb{E}}(\lambda_e - \lambda_i)$, which implies a positive relationship between n_e and $\bar{w}$. In $(n_e, \bar{w})$ space, we can plot a downward-sloping curve defined by (3) and a upward-sloping curve defined by (4), and their intersection determines equilibrium n_e and $\bar{w}$. An increase in κ e.g. reduces n_e, which lowers the number of ideas traded, and hence output, wages, and growth (Figure 2).

4 Technology Transfer with Credit Frictions

We now study the case in which the transfer of ideas is hindered by credit frictions, and form of liquidity is needed to facilitate the efficient exchange of ideas. Assume that the asset a is liquid in the sense that it can be transferred in the idea market from e to i. Since each share of a has a price ϕ and yields dividend δ^a, the accounting return on a is

$$1 + i^a = \frac{\phi' + Z'\delta^a}{\phi}.$$

Similarly, suppose there also exists an illiquid asset b which yields dividend δ^b but cannot be traded in the idea market – say, it is not portable, so it physically cannot be carried into this market and claims to it can be counterfeited (see Lester et al 2009 for details). The fixed supply of this illiquid asset is B. In equilibrium b must be priced fundamentally, and its return is

$$1 + i_t^b = \frac{1+g}{\beta}.$$

Define for future reference the *spread* between the illiquid and liquid asset as

$$s \equiv \frac{i^b - i^a}{1 + i^a} = \frac{(1+g)\phi}{\beta(\phi' + Z'\delta^a)} - 1. \tag{5}$$

For the most part, the model here works much as it did in the last section, and in particular, the value of implementing ideas is unchanged. However, consider now e with a^e in the idea market. Then e is bound by a constraint that says he cannot pay i any more that $x \equiv \frac{\phi + Z\delta^a}{Z} a^e$ (i.e. liquid asset holdings measured in terms of goods, normalized by productivity). If this constraint $p \leq x$ is not binding, the bargaining solution is as before

$$p = (\pi_1 - \pi_0)\left[(1-\theta)\lambda_e + \theta\lambda_i\right].$$

It it easy to show that the constraint does not bind iff

$$\lambda_e \leq B(\lambda_i, x) \equiv \frac{1}{1-\theta}\left[\frac{x}{\pi_1 - \pi_0} - \theta\lambda_i\right].$$

When $\lambda_e \geq B(\lambda_i, x)$, the constraint binds, and we have the following: if $\frac{x}{\pi_1-\pi_0} \geq \lambda_i$ then e gets the idea and pays $p = x$; if $\frac{x}{\pi_1-\pi_0} < \lambda_i$ then i there is no trade, because x does not cover the reservation price of i.[10]

The outcome is shown in Figure 3. There is no trade in region A_0 because $\lambda_i > \lambda_e$. There is no trade in A_3 because e cannot pay the reservation price. There is nonbinding trade in A_1 and binding trade in A_2.

We now describe equilibrium. The market for dividends clears at price Z. The illiquid asset market clears at the fundamental price $Z\delta^b\beta/(1-\beta)$. The goods market condition is slightly modified to

$$\bar{w} = \chi\left[N(1+\eta)f(H_1) + (1-N)\,f(H_0) + A\delta^a + B\delta^b\right], \tag{6}$$

where $A\delta^a + B\delta^b$ is the total dividend generated by liquid and illiquid assets. The equilibrium number of ideas successfully implemented is now given by

$$\begin{aligned} N &= n_i \int_0^1 \lambda_i dF_i(\lambda_i) + n_i\alpha_i \int_0^{\frac{x}{\pi_1-\pi_0}} \int_{\lambda_i}^1 (\lambda_e - \lambda_i) dF_e(\lambda_e|\lambda_i) dF_i(\lambda_i), \\ &= n_i \int_0^1 \lambda_i dF_i(\lambda_i) + n_i\alpha_i \bar{\mathbb{E}}(\lambda_e - \lambda_i; x) \end{aligned}$$

where $\bar{\mathbb{E}}(\lambda_e - \lambda_i; x)$ denotes $\mathbb{E}(\lambda_e > \lambda_i | \min\{\frac{x}{\pi_1-\pi_0}, \lambda_e\} > \lambda_i) \Pr(\min\{\frac{x}{\pi_1-\pi_0}, \lambda_e\} > \lambda_i)$. Therefore, the total number of ideas implemented by the innovators plus the additional ideas implemented by the entrepreneurs after trade which happens only when $\min\{\frac{x}{\pi_1-\pi_0}, \lambda_e\} > \lambda_i$.

The liquid asset market is cleared when, given the spread s, the demand for liquid asset is equal to the total stock $n_e a_e + n_i a_i = A$. The labor market is then cleared by the Walras law. We first derive the demand for liquid assets.

[10] See Silviera and Wright (forthcoming) for more details.

(a) Demand for liquidity

We can use the bargaining solution to derive the value function for entrepreneurs in the idea market

$$\begin{aligned}
V^e(a,Z) &= (1-\alpha_e)W_0^e(a,Z) + \alpha_e \int_{A_0} W_0^e(a,Z) \qquad (7)\\
&+\alpha_e \int_{A_1} \lambda_e W_1^e(a - p\frac{Z}{\phi + Z\delta^a}, Z) + (1-\lambda_e)W_0^e(a - p\frac{Z}{\phi+Z\delta^a}, Z)\\
&+\alpha_e \int_{A_2} \lambda_e W_1^e(0,Z) + (1-\lambda_e)W_0^e(0,Z)\\
&+\alpha_e \int_{A_3} W_0^e(a,Z).
\end{aligned}$$

where $\int_{A_j}(.)$ is the integral over region A_j in Figure 3. The first term is the payoff to having no possibility of trade; the second term is the payoff to having a possible trade but no gains from trade; the third is the payoff to trading at p; the fourth is the payoff to trading at $p = x \equiv \frac{\phi+Z\delta^a}{Z}a$; the final term is the payoff to having no trade because of the liquidity constraint. (7) can be reduced to

$$\begin{aligned}
V^e(a,Z) &= W_0^e(a,Z)\\
&+\alpha_e\theta\chi/w \int_{A_1} (\lambda_e - \lambda_i)Z(\pi_1 - \pi_0)\\
&+\alpha_e\chi/w_t \int_{A_2} \lambda_e Z(\pi_1 - \pi_0) - Za(\phi + Z\delta^a).
\end{aligned}$$

Notice that for e, his choice of a can affect the area of each region A_j, and hence the probability of trade, as well as the terms of trade in region A_2 where he pays all he has.

For i, neither the probability nor the terms of trade depend on a, and any liquid assets he brings to the idea market are simply carried into the next centralized market, which implies he is willing to hold a in equilibrium iff it is priced fundamentally. It is convenient to redefine the choice variable as $x = a\frac{\phi+Z\delta^a}{Z}$

instead of a. It is shown in the appendix that entrepreneur's decision problem w.r.t. x can be rewritten as

$$\max_x -sx + \alpha_e\theta \int_0^{\frac{x}{\pi_1-\pi_0}} \int_{\lambda_i}^{B(\lambda_i,x)} (\lambda_e - \lambda_i)(\pi_1 - \pi_0) dF_e(\lambda_e|\lambda_i) dF_i(\lambda_i)$$
$$+\alpha_e \int_0^{\frac{x}{\pi_1-\pi_0}} \int_{B(\lambda_i,x)}^{1} [\lambda_e(\pi_1 - \pi_0) - x] \, dF_e(\lambda_e|\lambda_i) dF_i(\lambda_i)$$

Here, the first term represents the cost of acquiring liquidity position x for the following idea market, and the remaining terms describe the benefits.

By the Leibniz Rule, the FOC is given by

$$-s + \ell(x) = 0,$$

where

$$\begin{aligned}
\ell(x) &= \frac{\alpha_e\theta}{(\pi_1-\pi_0)(1-\theta)^2} \int_0^{\frac{x}{\pi_1-\pi_0}} [x - \lambda_i(\pi_1 - \pi_0)] \, F_e'(B(\lambda_i, x)|\lambda_i) dF_i(\lambda_i) \\
&\quad -\alpha_e \int_0^{\frac{x}{\pi_1-\pi_0}} \int_{B(\lambda_i,x)}^{1} dF_e(\lambda_e|\lambda_i) dF_i(\lambda_i) \\
&\quad -\frac{\alpha_e\theta}{(\pi_1-\pi_0)(1-\theta)^2} \int_0^{\frac{x}{\pi_1-\pi_0}} [x - \lambda_i(\pi_1 - \pi_0)] \, F_e'(B(\lambda_i, x)|\lambda_i) dF_i(\lambda_i) \\
&\quad +\alpha_e \frac{1}{\pi_1-\pi_0} F_i'(\frac{x}{\pi_1-\pi_0}) \int_{\frac{x}{\pi_1-\pi_0}}^{1} [\lambda_e(\pi_1 - \pi_0) - x] \, dF_e(\lambda_e|\lambda_i).
\end{aligned}$$

In economic terms, $\ell(x_t)$ is e's marginal benefit from liquidity position x. The first term captures the marginal benefit of having more surplus from unconstrained trade (upward shift of the top boundary of region A_1). The second term captures the marginal loss due to the higher price paid by e (for every point in region A_2). The third term captures the marginal loss of losing surplus from constrained trade (upward shift of the bottom boundary of region A_2). The fourth term captures the marginal benefit of having more surplus from constrained trade (rightward shift of the right boundary of region A_2). We can further simplified the FOC to

$$\begin{aligned} s &= \ell(x) = \alpha_e \frac{1}{\pi_1-\pi_0} F_i'(\frac{x}{\pi_1-\pi_0}) \int_{\frac{x}{\pi_1-\pi_0}}^{1} [\lambda_e(\pi_1-\pi_0)-x]\, dF_e(\lambda_e|\lambda_i) \quad (8) \\ & -\alpha_e \int_0^{\frac{x}{\pi_1-\pi_0}} [1-F_e(B(\lambda_i,x)|\lambda_i)]\, dF_i(\lambda_i). \quad (9) \end{aligned}$$

We can show that $\ell(x)=0$ for $x \geq \pi_1-\pi_0$. Moreover, if s is too big, there is no $x>0$ that can satisfy the FOC.

It is obvious that since i has no liquidity need, he chooses $x=0$ if $s>0$, and is willing to hold any x if $s=0$. Therefore, there are two potential types of equilibrium. First, if $s>0$, then $n_e a_e = A$ and $a_i=0$. Second, if $s=0$, then $n_e a \leq A$ and $n_i a_i = A - n_e a_e$.

As in Wright (forthcoming), the market demand for liquidity $L(s;\bar{w})$ is continuous, strictly decreasing except possibly for horizontal segments, and hits $L(s;\bar{w})=0$ at finite s. Note that the demand curve is conditional on $\bar{w}$ because $\ell(x)$ depends on $(\pi_1-\pi_0)$ which in turns depends on the $\bar{w}$ determined in the labor market.

(b) Supply of liquidity

We now derive a supply curve of liquidity. Using the definitions of x, i_a and i_b, and setting $n_e a_e = A$, we can rewrite the spread as

$$\begin{aligned} s = s(x) &\equiv \frac{(1+g)\phi}{\beta(\phi' + Z'\delta^a)} - 1 \quad (10) \\ &= \frac{\phi a_e}{\beta x} - 1 \\ &= \frac{x - \delta^a A/n_e}{\beta x} - 1. \end{aligned}$$

This is a relation expressing the cost of liquidity s in terms of the liquidity position x. $s(x)$ can be interpreted as a supply curve with the following properties: $s(0)=-\infty, s'(x)>0, s''(x)<0$, and $s(\infty)=i^b=(1-\beta)/\beta$. Also, $s(x)=0$ iff $i^a=i^b$.

Definition An equilibrium BGP is a triple $(x^*, s^*, \bar{w}^*)$ that satisfies equations (6), (8), and (10).

We will now first consider a special case to highlight how the model works. We again consider the production function $f(H) = 1 - \exp(-H)$. Furthermore, assume entrepreneurs have all the bargaining power ($\theta = 1$), and assume the skill distributions, F_i and F_e, are uniform and independnet. It is shown in Appendix 2 that the asset market clearing condition can be rewritten as

$$AM(x, \bar{w}) \equiv s(\bar{x}) - \ell(x; \bar{w}) = 0.$$

With $\bar{w}$ on the vertical axis and $\bar{x}$ on the horizontal axis, the AM curve is weakly decreasing. Similarly, we can also define a goods market clearing condition

$$GM(x, \bar{w}) \equiv \bar{w} - \frac{\chi}{1+\chi}[1 + N\eta + A\delta^a + B\delta^b],$$

which is weakly increasing for small η. Therefore, there exists a balanced growth path $(x^*, s^*, \bar{w}^*)$ given by the intersection of the two curves.

Finally, we consider the effect of increasing the stock of liquid assets, $A\delta^a$, on the economy (but fixing the total amount of asset, $A\delta^a + B\delta^b$). Since an increase in $A\delta^a$ leads to an upward shift of the AM curve with the LM curve unaffected, the equilibrium x^*, s^*, $\bar{w}^*$ will all go up. As a result, the equilibrium growth rate of the economy increases as well. (Figure 4)

Holding the total asset fixed, as the stock of liquid assets goes up, the growth rate of the economy g increases. It will also improve allocation in the market for ideas, leading to a higher level of output in the goods market ($\bar{y}$), a lower interest spread (s) in the asset market, and a higher wage rate in the labor market ($\bar{w}$).

The intuition is that, when the stock of liquid asset increases, the interest spread has to drop to clear the asset market by inducing entrepreneurs to hold more liquid assets. As the liquidity constraints of entrepreneurs are relaxed, they choose to purchase and implement more ideas in production. This will increase the marginal productivity and thus wage rate of the workers. So the level of output rises. Better allocation and accumulation of ideas can also lead to a higher economic growth rate.

5 Endogenous Financial Activity

6 Empirical Evidence

In this section, we report some evidence to support the case that technology transfer can be an important part of the innovation process, and that credit market imperfections can hinder this process. Our empirical analysis makes use of the firm level data obtained from the World Bank Enterprize Surveys conducted between 2002 and 2005. The whole sample includes 4059 firms across 33 countries. We follow closely the statistical method employed by Carluccio and Falley (2009), but appropriately modify the sample and choice of variables to address our own research question.

Before going to the details of the empirical analysis, let us first highlight the following main findings:

1. In some countries (e.g., Germany), direct technology transfer from an arm's length outside party is an important way for firms to acquire new technology.

2. Firms' decision to transfer technology is positively correlated with the financial development in a country. This is particularly significant for small firms.

3. Financial development is a significant and positive predictor of a firm's

decision to transfer technology.

Using responses to survey questions, we determine whether or not a firm has acquired technology in 2002-2005. Given our interest in direct technology transfer, we restrict our attention to arm's length technology transfers from outside parties. In particular, firms in our data are asked to report the most important way that they acquire new technology in the last 36 months. We focus on technology transfers through new licensing or turnkey operations obtained from international sources, domestic sources as well as universities and public institutions. We do not include transfers resulting from hiring, transfers from parent companies, internal development, and development in cooperation with other partners.

Table 1 in the appendix reports cross-country summary statistics regarding the fraction of firms with direct technology transfers, and its relationship to financial development and firm size. This direct transfer seems to be an important source of technology acquisition in some countries. For example, 12.6% of German firms in the survey reported that the most important way they acquired technology is through new licensing or turnkey operations from international sources, domestic sources, or obtained from universities or public institutions.

To study the effects of financial development on technology transfers, we follow the literature to proxy financial development of a country by the ratio of private credit to GDP. This variable is taken from Beck, Demirg-Kunt and Levine (1999). Table 2 indicates that, overall, a higher level of financial development is associated with higher rates of technology transfers. The positive correlation is more significant for smaller firms, and tends to become smaller or even reversed as firm size becomes larger.

Table 3 to 5 report results from three regressions which study the partial effects of financial development on technology transfers. Other control variables in the regression include market size, price level of investment, openness, investment level, firm size, presence of foreign capital and industry dummies. Variable definitions can be found in the appendix.[11] The first regression is an naive OLS regression. To deal with the endogeneity problem in the second model, we follow Djankov, McLiesh and Shleifer (2007) to instrument the private credit over GDP by legal origin and perform a 2SLS regression. The third model is a probit regression. The general pattern we found over different models and different specifications is that the level of financial development (proxied by private credit over GDP) have positive and diminishing effects on technology transfer. Also, the effect of financial development is diminishing in firm size.

While our analysis focuses on how a firm's technology transfer decision depends on the level of financial development in a country, there is also an empirical literature which studies how the decision to acquire technology depends on a firm's own liquidity and financial constraint. Montalvo and Yafeh (1994) e.g. examines investment in foreign technology by Japanese firms in the form of licensing agreements and concluded that "liquidity is an important consideration in the firm's decision to invest in foreign technology".[12] In particular, their analysis found that "... liquidity matters in the firm's decision to acquire technology. Cash flow has a positive impact, and $REALCF$ (cash flow of firms with limited access to main bank loans) is always positive and significant. Furthermore, the coefficient of $REALCF$ is much higher than that of cash flow, implying that non-keiretsu firms are more liquidity constrained than group-affiliated firms". This conclusion is obviously consistent with the implications

[11] See Carluccio and Falley for more detailed discussion of the statistical approach.

[12] As pointed out by Montalvo and Yafeh, "the terms of the agreements vary, but often include a combination of fixed up-front payments, 'running royalty' (a percentage of sales), fixed annual fees, and an item involving export restrictions and/or exclusive dealing for the recipient Japanese firm".

of our model as well as our empirical analysis.

7 Conclusion

Appendix

Appendix 1: Entrepreneur's Choice of x

It is convenient to redefine the state variable as $x = a\frac{\phi + Z\delta^a}{Z}$ instead of a, and rewrite the value function $\tilde{V}^e(x, Z) = V_t^e(a, Z)$,[13] where

$$\begin{aligned}
\tilde{V}^e(x, Z) &= \text{constant} + \chi/\bar{w}x \\
&+ \alpha_e \theta \chi/\bar{w} \int_0^{\frac{x}{\pi_1 - \pi_0}} \int_{\lambda_i}^{B(\lambda_i, x)} (\lambda_e - \lambda_i)(\pi_1 - \pi_0) dF_e(\lambda_e|\lambda_i) dF_i(\lambda_i) \\
&+ \alpha_e \chi/\bar{w} \int_0^{\frac{x}{\pi_1 - \pi_0}} \int_{B(\lambda_i, x)}^{1} \left[\lambda_e(\pi_1 - \pi_0) - x\right] dF_e(\lambda_e|\lambda_i) dF_i(\lambda_i),
\end{aligned}$$

with

$$B(\lambda_i, x) = \frac{1}{1-\theta}\left[\frac{x}{\pi_1 - \pi_0} - \theta\lambda_i\right].$$

By (5), we can rewrite the interest spread as

$$\begin{aligned}
sx' &= \left(\frac{(1+g)\phi}{\beta(\phi' + Z'\delta^a)} - 1\right) x' \\
&= \frac{(1+g)\phi}{\beta(\phi' + Z'\delta^a)} x' - x' \\
&= \frac{(1+g)\phi a'}{\beta Z'} - x',
\end{aligned}$$

implying $\phi a' = \frac{\beta}{1+g} sx'Z' + \frac{\beta}{1+g} x'Z'$. Substituting this term to the choice problem of asset holding

$$\max_{a'} -\frac{\chi}{w}\phi a' + \beta V^e(a', Z'),$$

we can rewrite the problem as choosing x to maximize

$$\begin{aligned}
&-\frac{\chi}{\bar{w}}\beta s x + \beta\alpha_e\theta\frac{\chi}{\bar{w}} \int_0^{\frac{x}{\pi_1 - \pi_0}} \int_{\lambda_i}^{B(\lambda_i, x)} (\lambda_e - \lambda_i)(\pi_1 - \pi_0) dF_e(\lambda_e|\lambda_i) dF_i(\lambda_i) \\
&+\beta\alpha_e\frac{\chi}{\bar{w}} \int_0^{\frac{x}{\pi_1 - \pi_0}} \int_{B(\lambda_i, x)}^{1} \left[\lambda_e(\pi_1 - \pi_0) - x\right] dF_e(\lambda_e|\lambda_i) dF_i(\lambda_i)
\end{aligned}$$

[13] This is analogous to the way monetary economists define the state to be real rather than nominal balances, although we do it for slightly different reasons.

or simply

$$-sx + \alpha_e \theta \int_0^{\frac{x}{\pi_1 - \pi_0}} \int_{\lambda_i}^{B(\lambda_i, x)} (\lambda_e - \lambda_i)(\pi_1 - \pi_0) dF_e(\lambda_e|\lambda_i) dF_i(\lambda_i)$$
$$+\alpha_e \int_0^{\frac{x}{\pi_1 - \pi_0}} \int_{B(\lambda_i, x)}^{1} [\lambda_e(\pi_1 - \pi_0) - x] \, dF_e(\lambda_e|\lambda_i) dF_i(\lambda_i)$$

Appendix 2: Equilibrium BGP for Special Case: $f(H) = 1 - \exp(-H)$, $\theta = 1$, **F_i and F_e are uniform**

When $\theta = 1$, $B_t(\lambda_i, x)$ is vertical, region A_2 vanishes. Suppose λ_e and λ_i are independent. Then

$$\begin{aligned}
\ell(x) &= \alpha_e \frac{1}{\Delta}\int_{\frac{x}{\Delta}}^{1} [\lambda_e(\pi_1 - \pi_0) - x]\, dF_e(\lambda_e|\lambda_i) - \alpha_e \int_0^{\frac{x}{\Delta}} [1 - F_e(B(\lambda_i, x)|\lambda_i)]\, dF_i(\lambda_i). \\
\ell(x) &= \alpha_e \int_{\frac{x}{\Delta}}^{1} \left[\lambda_e - \frac{x}{\Delta}\right] dF_e(\lambda_e),
\end{aligned}$$

where $\Delta = \eta - \frac{w}{Z}\log(1+\eta)$.Note that $\ell(0) = \alpha_e E(\lambda_e)$ and $\ell(\Delta) = 0$. Moreover,

$$\ell'(x) = -\frac{\alpha_e}{\Delta}[1 - F_e(\frac{x}{\Delta})] \leq 0$$

The asset market clearing condition becomes

$$\begin{aligned}
AM(x, \bar{w}) &\equiv s(x) - \ell(x; \bar{w}) \\
&= \frac{x - \delta^a A/n_e}{\beta x} - 1 - \alpha_e \int_{\frac{x}{\Delta}}^{1} \left[\lambda_e - \frac{x}{\Delta}\right] dF_e(\lambda_e) \\
&= 0
\end{aligned}$$

Note that $AM(0, \bar{w}) = -\infty, AM(\Delta, \bar{w}) > 0$ for small δ^a, and

$$\frac{d}{d\bar{x}} AM(x, \bar{w}) > 0.$$

So for any given $\bar{w}$, a unique $x = x^{AM}(\bar{w})$ clears the asset market. Moreover,

$$\frac{d}{d\bar{w}} AM(x, \bar{w}) = \log(1+\eta)\frac{x}{\Delta^2}\alpha_e \left[1 - F_e(\frac{\bar{x}}{\Delta})\right] \geq 0.$$

Therefore, with $\bar{w}$ on the vertical axis and x on the horizontal axis, the AM curve is weakly decreasing:

$$\frac{dx}{d\bar{w}}|_{AM} = -\frac{\frac{d}{dx}AM(x, \bar{w})}{\frac{d}{d\bar{w}}AM(x, \bar{w})} \leq 0.$$

We can also define a labor market clearing condition

$$LM(x, \bar{w}) \equiv \bar{w} - \frac{\chi}{1+\chi}[1 + N\eta + A\delta^a + B\delta^b],$$

with $N = n_i \int_0^1 \lambda_i dF_i(\lambda_i)\eta + n_i\alpha_i \int_0^{\frac{x}{\Delta}} \int_{\lambda_i}^1 (\lambda_e - \lambda_i) dF_e(\lambda_e) dF_i(\lambda_i)$. Note that $LM(., 0) < 0$, and $LM(., \bar{w}) > 0$ for sufficiently large $\bar{w}$, and

$$\frac{d}{d\bar{w}} LM(., \bar{w}) = 1 - \log(1+\eta)\frac{\chi}{1+\chi}\frac{1}{\Delta}[n_i\alpha_i \int_{\frac{x}{\Delta}}^1 (\lambda_e - \frac{x}{\Delta}) dF_e(\lambda_e)\eta] \geq 0,$$

for small η. So for any given x, a unique $\bar{w} = \bar{w}^{LM}(x)$ clears the asset market when η is small. Moreover,

$$\frac{d}{dx} LM(x, .) = -\frac{\chi}{1+\chi}\frac{1}{\Delta}[n_i\alpha_i \int_{\frac{x}{\Delta}}^1 (\lambda_e - \frac{x}{\Delta}) dF_e(\lambda_e)\eta] \leq 0.$$

Therefore, the LM curve is weakly increasing:

$$\frac{dx}{d\bar{w}}|_{LM} = -\frac{\frac{d}{dx} LM(x, \bar{w})}{\frac{d}{d\bar{w}} LM(x, \bar{w})} \geq 0$$

Note that $\bar{w} \leq \bar{w}_{\max} = \frac{\chi}{1+\chi}[1 + n_i \int_0^1 \lambda_i dF_i(\lambda_i)\eta + n_i\alpha_i \int_0^1 \int_{\lambda_i}^1 (\lambda_e - \lambda_i) dF_e(\lambda_e) dF_i(\lambda_i)\eta]$. So when $x \geq \Delta_{\max} = \eta - \bar{w}_{\max} \log(1+\eta)$, then the LM curve becomes flat.

Fixing the total stock of assets $A\delta^a + B\delta^b$, a rise in $\delta^a A$ will only shift up the AM curve, and does not affect the LM curve. So the equilibrium x and $\bar{w}$ increase. From the AM condition, this will lead to a lower spread s. Also, the equilibrium number of ideas successfully implemented N goes up, and thus the output and growth also rise.

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FIGURES

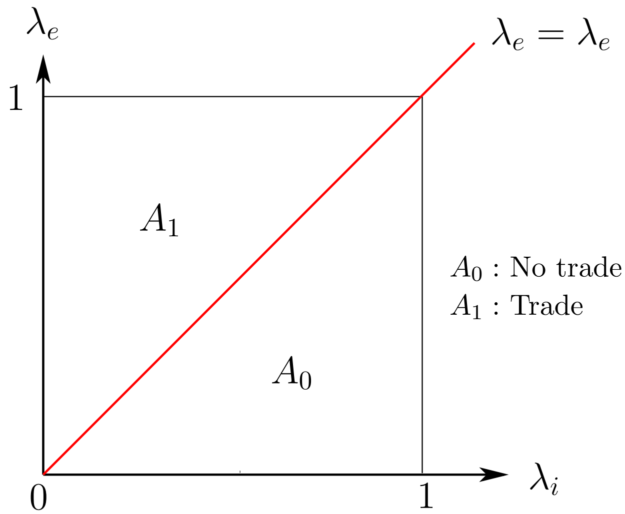

Figure 1: Bargaining Outcome (Without Financial Frictions)

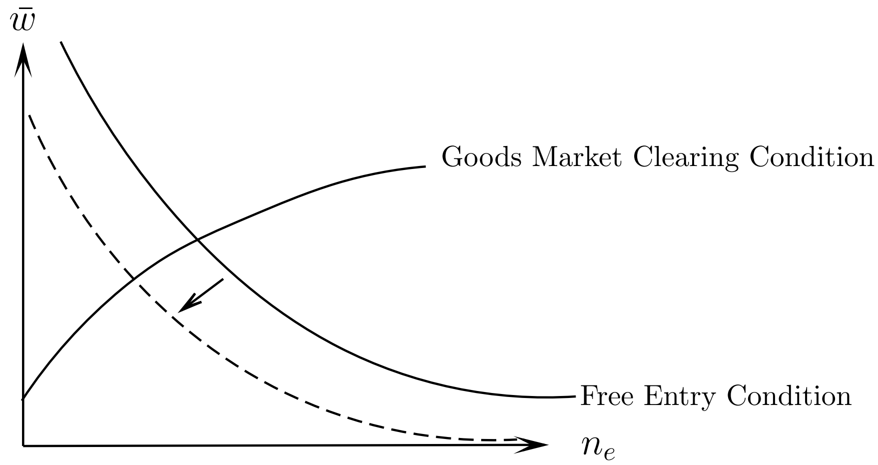

Figure 2: Equilibrium with Free Entry of Entrepreneurs and Effects of Increasing Entry Cost κ

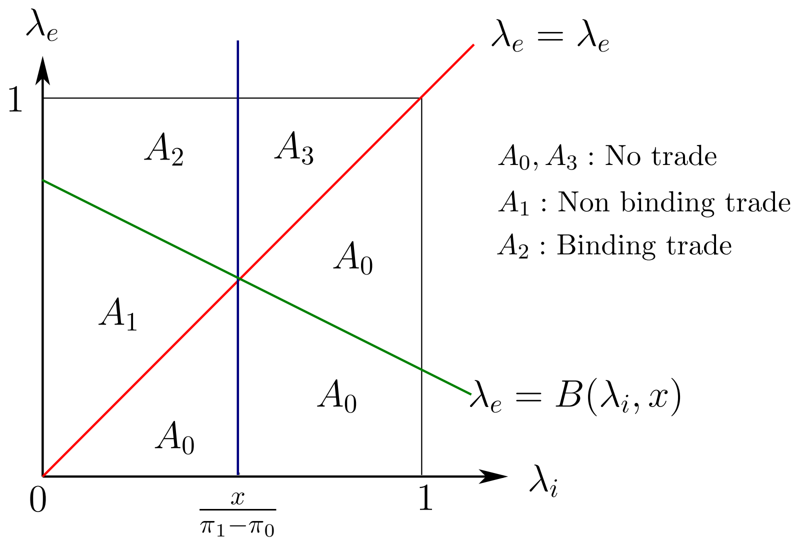

Figure 3: Bargaining Outcome (With Financial Frictions)

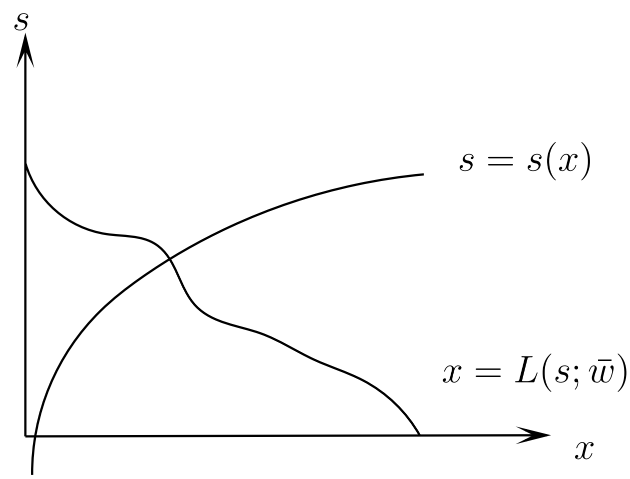

Figure 4: Asset Market Clearing

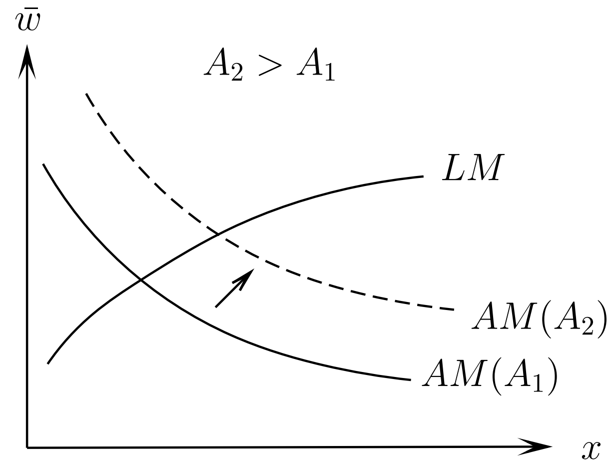

Figure 5: Effects of Increasing the Stock of Liquid Assets

Empirical Analysis

Variable Definitions

key:	* indicates a firm-specific variable, ^ a country-specific. [2005:***] indicates the World Bank Enterprise Survey question the variable was generated from. Other sources are cited.

Note: Regressions follow Carluccio and Falley (2009).

Dependent

Technology Transfer*: Binary variable equal to one if the firm's (self reported) most important source of technology is any of: "new licensing or turnkey operations from international sources," "new licensing or turnkey operations from domestic sources," "obtained from universities or public institutions." [2005:Q61b]

Independent – Explanatory

Private credit/GDP^: The ratio of private credit by deposit money banks to GDP, used as a proxy for a country's level of financial development. Taken from Beck et al (1999).

Private credit/GDP^2: The previous term squared.

Independent – Instruments

Legal origin^: A set of three dummy variables, French-civil, German-civil, and common law, indicating the origin of a country's legal system. A country's legal code can have multiple influences. Taken from Djankov et al (2007), and The CIA World Factbook.

Independent – Controls

Market size^: The population of the country in which a firm operates. Taken from Penn World Tables 6.3.

Price level of investment^: PPP over investment level, divided by exchange rate with US$, multiplied by 100. Taken from Penn World Tables 6.3.

Openness^: Exports plus imports, divided by GDP. Taken from Penn World Tables 6.3.

Investment level^: Investment as a share of GDP. Taken from Penn World Tables 6.3.

Firm size*: Number of permanent, full-time employees employed at a firm, self reported. [2005:Q66a]

Presence of foreign capital*: Dummy variable equal to one if a positive percentage of a firm is owned by foreign individuals or businesses, self reported. [2005:S5b]

Industry dummies*: A set of seven dummy variables designating a firm's industry. A firm belongs to a certain industry if the majority of its operations are in the specified field. Industries are: mining, construction, manufacturing, transport, wholesale, real estate, hotel and restaurant services, and "other" if none of these are applicable. [2005:Q2a-g; 2002:q2a-g]

Table 1: Summary of Country Statistics for 2005 World Bank Enterprise Survey

-all firm sizes, all firm types

Country	Technology transfer:	# obs	Mean	Std. Dev.	Private credit/GDP
Albania		82	0.024	0.155	0.118
Armenia		182	0.005	0.074	0.069
Azerbaijan		164	0.110	0.314	
Belarus		93	0.011	0.104	
Bosnia		89	0.011	0.106	0.391
Bulgaria		83	0.048	0.215	0.378
Croatia		94	0.000	0.000	0.563
Czech Rep.		78	0.077	0.268	0.330
Estonia		40	0.025	0.158	0.619
Georgia		56	0.054	0.227	0.113
Germany		277	0.126	0.333	1.109
Greece		206	0.024	0.154	0.715
Hungary		91	0.099	0.300	0.475
Ireland		191	0.037	0.188	1.421
Kazakhstan		182	0.033	0.179	0.276
Korea		94	0.128	0.335	0.894
Kyrgyzstan		86	0.093	0.292	0.072
Latvia		51	0.098	0.300	0.549
Lithuania		57	0.053	0.225	0.328
Macedonia, FYR		63	0.032	0.177	0.226
Moldova		136	0.044	0.206	0.208
Poland		326	0.058	0.235	0.277
Portugal		126	0.016	0.125	1.403
Romania		247	0.045	0.207	0.166
Russian Federation		178	0.039	0.195	0.227
Serbia&Montenegro		110	0.018	0.134	0.229
Slovak Republic		50	0.060	0.240	0.314
Slovenia		65	0.015	0.124	0.530
Spain		185	0.016	0.127	1.301
Tajikistan		70	0.014	0.120	
Turkey		162	0.025	0.156	0.184
Ukraine		181	0.028	0.164	
Uzbekistan		64	0.016	0.125	

Table 2: Percent of firms engaging in technology transfer, World Bank Enterprise Survey 2005

Number of employees:	All	2-10	11-50	51-100	101-250	251-500	501-1000	>1000
Below mean private credit/GDP	4.16	2.25	4.06	5.47	5.60	5.16	10.17	4.08
Above mean private credit/GDP	5.13	4.76	5.60	6.67	2.84	4.21	7.50	7.32

Tables 2 indicates that a higher level of financial development is associated with higher rates of TT for smaller firms, but that this trend slows and reverses as firm size becomes larger.

Table 3: 'Naive' OLS Regression of TT on private credit, uninstrumented

Dependent variable: Technology transfer						
	(1)	(2)	(3)	(4)	(5)	(6)
Private credit/GDP	.0138857^{+} (.008022)	.0286977^{+} (.0158311)	.0275749^{+} (.0158913)	.1307984** (.0381235)	.1607428** (.0464473)	.1649471** (.0467721)
Private credit/GDP^2				-.0793883** (.0253092)	-.0838725** (.0277401)	-.0870206** (.0278705)
Log market size		.0191154** (.0039222)	.0181353** (.0039426)		.0158355** (.0040651)	.0147805** (.0040816)
Price level of investment		-.0004831 (.0004288)	-.0004313 (.0004298)		-.0004973 (.0004283)	-.000449 (.0004293)
Openness		.0005878** (.0001586)	.0005453** (.0001598)		.0004829** (.0001622)	.0004353** (.0001635)
Investment level		-.000955^{+} (.0005261)	-.0009599^{+} (.0005274)		-.0016238** (.0005702)	-.0016491** (.0005711)
Log firm size			.0060541** (.0022002)			.0061931** (.0021979)
Presence of foreign capital			.0049709 (.0110472)			.0049281 (.0110334)
Industry dummies	no	no	yes	No	no	yes
Intercept	.0395144** (.0055075)	-.1503986** (.047615)	-.1730303** (.0507578)	.0152906 (.0094814)	-.1210729* (.0485387)	-.1442761 (.0515241)
# observations	3587	3509	3509	3587	3509	3509

$^{+}$ Significant at 10% level.
* Significant at 5% level
** Significant at 1% level

Table 4: 2SLS Regression of TT on private credit

Dependent variable: Technology transfer						
	(1)	(2)	(3)	(4)	(5)	(6)
Private credit/GDP^Ψ	.0644579** (.0136873)	.3358211** (.0608203)	.3201715** (.0585148)	.5516802** (.0763756)	.4168064** (.0764277)	.407273** (.0754843)
Private credit/GDP^{2} ^Ψ				-.3208835** (.0494619)	-.0768176+ (.0448097)	-.0802096+ (.044665)
Firm size*private credit/GDP	-.0000421* (.0000178)	-.0000825** (.0000224)	-.0000807** (.0000221)	-.0000436* (.0000181)	-.0000719** (.000023)	-.0000702** (.0000226)
Log market size		.026257** (.0043443)	.0254732** (.0043348)		.0223161** (.0048683)	.0214516** (.0048347)
Price level of investment		-.0067486** (.0012791)	-.0064008** (.0012251)		-.0059457** (.0013475)	-.0056167** (.0012873)
Openness		.0010222** (.0001865)	.0009774 ** (.0001848)		.0008692** (.0002047)	.0008213** (.0002023)
Investment level		-.0044061** (.0008579)	-.0041468** (.0008274)		-.0045714** (.000853)	-.0043473** (.0008255)
Firm size	.0000289* (.0000129)	.0000504** (.0000158)	.0000465** (.0000156)	.0000274* (.0000131)	.0000445** (.000016)	.0000406+ (.0000158)
Presence of foreign capital			.0138316 (.011196)			.0139985 (.0110671)
Industry dummies	no	no	yes	no	no	yes
Intercept	.0121151* (.0080953)	.0350161 (.0612051)	.0085095 (.0622492)	-.0931686** (.0181897)	.0377721 (.0604806)	.0121238 (.0615633)
# observations	3587	3509	3509	3587	3509	3509

+ Significant at 10% level.
* Significant at 5% level
** Significant at 1% level
Ψ Instrumented by legal origin.

Table 5: Probit Regression of TT on private credit

Dependent variable: Technology transfer			
	(1)	(2)	(3)
Private credit/GDP[Ψ]	.5639767**	.8845314**	.893373**
	(.1146505)	(.3044448)	(.3001828)
Firm size*private credit/GDP	-.0004046* (.000181)	-.0003187 (.0002065)	-.0003148 (.000203)
Log market size		.2618082**	.2544041**
		(.0433897)	(.0437545)
Price level of investment		-.0208048** (.0072867)	-.0211415** (.0071656)
Openness		.0090459**	.0089023**
		(.0018062)	(.0018172)
Firm size	.000275*	.0002194[+]	.0002107**
	(.0001152)	(.0001303)	(.0001297)
Industry dummies	no	no	yes
Intercept	-1.950546**	-4.274277**	-4.34269**
	(.0639501)	(.5348244)	(.5722597)
# observations	3587	3509	3467

[*] Significant at 5% level
[**] Significant at 1% level
[Ψ] Instrumented by legal origin.