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Liquidity and the Market for Ideas*

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Abstract

We study markets where innovators can sell ideas to entrepreneurs, who may be better at implementing them. These markets are decentralized, with random matching and bargaining. Entrepreneurs hold liquid assets lest potentially profitable opportunities may be lost. We extend existing models of the demand for liquidity along several dimensions, including allowing agents to put deals on hold while they try to raise funds. We determine which ideas get traded in equilibrium, compare this to the efficient outcome, and discuss policy implications. We also discuss several special aspects of the market for ideas, as opposed to generic consumption goods, including: they are intermediate inputs; they are indivisible; and they are at least partially public (nonrival) goods.

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1 Introduction

We take it for granted that people understand that the development and implementation of new ideas is one of the major factors underlying economic performance.[1] In this vein, the concept of *technology transfer* is important to innovators and entrepreneurs looking to come up with and commercialize new technologies, and also to policy makers seeking to spur economic development. The issue is this: When innovators come up with new inventions, or projects, or ideas, should they try to implement them themselves, say through start-up firms? Or should they try to sell them, perhaps to established firms, or more generally to entrepreneurs who may be better at implementing these ideas?

If agents are heterogeneous in their abilities to come up with ideas and to extract their returns, one can imagine that some will specialize in innovation while others will specialize in implementation or commercialization. A superior allocation of resources will generally emerge when those who have the ideas are not necessarily those who implement them. Scholars in the "knowledge transactions field" share the view that the transfer of ideas from innovators to entrepreneurs leads to a more efficient use of resources, making all parties better off, and increasing the incentives for investments

[1]Both the inputs to and outputs of this process are important. On the input side, research and development expenditures account for 3% of US GDP, and according to a survey by the Association of University Technology Managers, the licensing of innovations just by universities, hospitals, research institutions, and patent management firms added more than $40 billion to the economy in 1999 and supported 270,000 jobs. On the output side, it is obvious that new ideas and technologies are essential to production and growth, and going back to Schumpeter (1934) it is often said that the creation of new firms is a significant mechanism through which new technologies are implemented.

in research. 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."[2]

Obviously, however, this requires some mechanism – say, some *market* – for the exchange of ideas, and the details of how this mechanism works could in principle have a big impact on outcomes. This is the subject of the current study.

Our analysis is related to the work of Holmes and Schmitz (1990, 1995), although we also deviate considerably from their approach. What we share with them is, in their words, the following: "The model has two key features. The first crucial assumption is that opportunities for developing new products repeatedly arise through time... The second key feature is that we assume that individuals differ in their abilities to develop emerging opportunities." Hence, "There are two tasks in the economy, developing products and producing products previously developed" (Holmes and Schmitz 1990, p. 266-7). Where we differ is the way we envision the market where ideas or projects get traded: they model it as a centralized market in competitive

[2] As reported in a recent special feature in *The Economist* (Oct. 2005) on ideas, patents and related topics, "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 on 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*" (p.6, emphasis added). And they quote Henry Chesbrough as saying "You see people innovating and creating new ideas and technologies, but not taking them all the way through to the market. They carry it to a certain stage and then hand the baton on to others who bring it on to commercialization." Of course, one could imagine innovators trying to buy implementation expertise from entrepreneurs, but the usual view is that such expertise is largely tacit and difficult to measure, so it seems more natural for the ideas to be sold to implementers. See also Teece et al. (1997), Pisano and Mang (1993), and Shane (2002).

equilibrium, while we take seriously the notion that there are considerable frictions in this market.

We think it is clear that there is in reality no centralized market for ideas. Innovators do not simply choose a quantity of ideas to supply to maximize profit taking as given the competitive price, and entrepreneurs do not simply choose how many new ideas to buy at a given price. The idea market is in actuality much more *decentralized*. Hence, we model it using search theory, with random matching and bilateral bargaining between innovators and entrepreneurs. Also, in accordance with a large literature regarding entrepreneurs and liquidity constraints, as discussed below, we consider the possibility that the *availability of liquid assets* may be important for closing deals. When there are imperfect markets for the exchange of ideas, it is not only relevant who you meet and what they know, there is also the issue of how to pay for it. The fact that you are better at implementing a project means little if you have nothing to offer me in exchange.

This is especially important in highly decentralized markets, where it is easy to imagine reasons why I might be reluctant to give you my idea for a promise of future payment – e.g. once I give you the information, you might decide not to pay, and it can be hard to take an idea back. Hence, it is easy to imagine that quid pro quo may be the order of the day: "You want my idea? Show me the money." Given this, entrepreneurs may choose to keep liquid assets, in case they come across a potentially profitable opportunity that could be lost if there is not a quick agreement. Naturally, how much liquidity they hold depends on the cost, which may be determined at least in part by policy. For example, the opportunity cost of carrying the most liquid asset, cash, is the nominal interest rate; more generally, the cost of liquidity is a higher return on alternative investment opportunities.

Our view that liquidity broadly speaking matters in this context is by no means new. Evans and Jovanovic (1989) e.g. find that the decision to become an entrepreneur depends positively on wealth, and interpret this as evidence of financial constraints. They conclude that the "liquidity constraint is binding for virtually all the individuals who are likely to start a business." They predict that if such constraints were removed, the probability of becoming an entrepreneur would increase by 34%. Many others come to similar conclusions.[3] To be fair, Lusardi and Hurst (2004) provide a dissenting opinion: while they also find a positive correlation between wealth and the probability a household subsequently owns a business, they suggest it is at least partly due to differences between business owners and non-owners in abilities, preferences or background, rather than liquidity.[4]

For at least two reasons, this debate is not pivotal for what we want to say. First, ideas are not only inputs to *new* businesses, but also existing

[3] See Evans and Leighton (1989), Holtz-Eakin et al. (1994), Fairlie (1999), Quadrini (1999, 2000), Gentry and Hubbard (2000), Paulson and Townsend (2000), Guiso, Sapienza and Zingales (2001), and Lel and Udell (2002).

[4] They conclude "Our results do not imply that any given household wanting to start a small business has unlimited access to credit at reasonable borrowing rates. Given optimal lender behavior, and common sense, such results would be implausible. We do conclude, however, that even if some households that want to start small businesses are currently constrained in their borrowing, such constraints are not empirically important in deterring the majority of small business formation in the United States. This may simply reflect the fact that the starting capital required for most businesses is sufficiently small. ... Alternatively, even if the required starting capital for some small businesses is high, existing institutions and lending markets in the United States appear to work sufficiently well at funnelling funds to households with worthy entrepreneurial projects."

enterprises, and liquidity constraints may impinge on the scale of operations as well as the probability of a start up. Second, we will remain agnostic and construct a model where by varying parameters we cover the case where liquidity is critical, the case where it is irrelevant, and anything in between. Moreover, the way we model liquidity is quite different than previous work on entrepreneurship, where various credit market imperfections are imposed in sometimes rather ad hoc ways.[5]

We also emphasize that liquidity is *endogenous* here: entrepreneurs choose how much to hold, depending on factors such as interest rates, market frictions, etc. In this sense our model is related to some work in monetary theory, and particular we follow Lagos and Wright (2005) by assuming agents sometimes trade in centralized markets and sometimes in decentralized markets. But while we adopt that feature, we also extend the framework in several ways that are important for our purposes. First, to the extent that ideas are intermediate inputs, we stress that operation of the idea market can spill over to other markets, and especially to wages and employment. Second, we take seriously the notion that there may be a public good aspect at play: the fact that I tell you my idea does not mean that I cannot also get some value out of it.

Third, mainly because of the previous points, we argue that monetary policy may be more potent than is commonly understood from existing mod-

[5] Some people simply assume there is no credit (Lloyd-Ellis and Bernhardt 2000 and Buera 2005), some assume credit is exogenously limited to a fixed multiple of wealth (Evans and Jovanovic 1989), some try to model it using moral hazard (Aghion and Bolton 1996), and some using asymmetric information (Fazzari et al. 1988, 2000).

els where liquidity is only relevant for trading consumption goods. Fourth, since ideas are indivisible and have random valuations, and since trades may be liquidity constrained, the bargaining problem may be nonconvex, and as a technical contribution we show how to deal with this using lotteries. Finally, in what is perhaps the most interesting innovation, agents with insufficient liquidity can attempt to put deals on hold and raise additional funds in the centralized market; the probability this attempt fails is what parameterizes the extent of the liquidity problem. All of this goes well beyond existing work in the related literature.

The rest of the paper is organized as follows. Section 2 lays out our basic assumptions. Section 3 discusses the centralized market, and Section 4 discusses the decentralized market where ideas are traded. Section 5 puts things together to characterize equilibrium. Section 6 takes up various extensions. Section 7 concludes. Technical results are relegated to the Appendix.[6]

2 Basic Assumptions

Time is discrete and continues forever. Alternating over time, there are two types of markets: a centralized market, denoted CM, where agents perform

[6] We mention some other related work. Several studies consider the transfer of ideas as a strategic action among firms, including Katz and Shapiro (1986), Gallini and Winter (1985), and Shepard (1994). Baccara and Razin (2004) consider strategic behavior among agents forming a team to implement an idea. Anton and Yao (1994, 2002) study markets where buyers do not know the value of an idea, and sellers are reluctant to reveal it because buyers may not pay afterwards. Others focus on licensing contracts in terms of incentives, including Aghion and Tirole (1994) and Arora (1995). There is a literature that focuses on university inventions, including Lowe (2003), Shane (2002), and Jensen and Thursby (2001). Chari, Golosov and Tsyvinski (2004) study the effects of taxation, den Haan, Ramey and Watson (2003) study matching between entrpreneurs and lenders, and Serrano (2005) studies empirically the market for patent transfers.

the usual activities of working, consuming and adjusting their assets; and a decentralized market, denoted DM, where agents meet bilaterally and can trade ideas. Agents have discount factor β between one DM and the next CM, and discount factor δ between the CM and the next DM, where $\delta\beta < 1$. There are large numbers of two types of agents: *innovators*, denoted i, who are relatively good at coming up with ideas, and *entrepreneurs*, denoted e, who may be better at implementing them. For now the measures of i and e, denoted N_i and N_e, are exogenous.

Every time the DM opens, innovator i gets a new idea I that has value $R_i \geq 0$ if he implements it himself, where R_i is drawn from CDF $F_i(\cdot)$, and is realized in the next CM. To keep things simple, if not implemented in one CM, the value of I in the following CM is an i.i.d. draw. Hence, if i finds himself in the CM with idea I, he will always implement it, since he gets a new R_i in any event. Entrepreneur e does not get ideas on his own, but if he meets i with an idea I worth R_i to him, it has value $R_e \geq 0$ to e, where R_e is drawn from $F_e(\cdot|R_i)$. When convenient we sometimes assume the densities $F_i'(R_i)$ and $F_e'(R_e|R_i)$ exist and are continuous, but this is not strictly necessary.[7]

One may well ask, *what exactly is an idea*? One view is that idea I is an intermediate input into some production process that can be implemented

[7] As a special case, if R_i and R_e are independent, we can say what matters is only the match between idea I and agent j. Another special case discussed in Section 6.1 is the one with $R_i = \bar{R}_i$ with probability 1, including $\bar{R}_i = 0$, where i is are purely an "idea man" who cannot implement anything. We could easily allow entrepreneurs to come up with some of their own ideas, or even reduce the model a single type – all agents get ideas from $F(R)$, but an idea worth R to you is worth $\hat{R}$ to me, drawn from $\hat{F}(\hat{R}|R)$. The reason for having two types is that it will be interesting to endogenize their numbers.

by agent j with technology $f_j(\mathbf{h}, I)$, where $\mathbf{h}$ is a vector of inputs, including labor. Given I, j solves

$$R_j(I) = \max_{\mathbf{h}} \{f_j(\mathbf{h}, I) - \mathbf{wh}\}, \tag{1}$$

where $\mathbf{w}$ is a vector of factor prices, including wages. This is important because it shows the allocation of ideas can affect employment, wages, and other variables in general equilibrium, and having the wrong agent implementing I can have a big impact on economic aggregates. However, to ease the presentation we begin with the case where $R_j = f_j(I)$ does not require additional inputs, and return to the general specification in Section 6.4.

We assume ideas are indivisible: either you tell me or you don't. We assume there is no private information: in a meeting, both agents know (R_i, R_e), even though e cannot implement I without i giving him the details. For example, if your idea is for a restaurant with some new cuisine, you can let me taste a sample without necessarily giving me the recipe. We abstract from informational frictions here *not* because they are uninteresting, but because we want to focus on different issues; several papers mentioned in the Introduction already consider private information.

We do take seriously the notion that there may be a public good aspect involved: the fact that you give me idea I does not mean that you cannot also use it. One way to capture this is to assume that if agent j is the only one to implement I he gets R_j, while if another agent also implements it then j gets $\lambda_j R_j$. If $\lambda_j = 1$, e.g., ideas are pure public (nonrival) goods. In general, if i sells I to e and both implement, they get $\lambda_i R_i$ and $\lambda_e R_e$; if i keeps it for himself, they get R_i and 0 respectively. To simplify the presentation we begin with the case $\lambda_i = 0$ and $\lambda_e = 1$. This can be interpreted as saying that i does not also implement an idea once he sells it – say, because there is only room for one new restaurant in town, or more generally, stepping outside the model, perhaps because of something like an exclusive licensing agreement. We return to the general case in Section 6.3.

If i and e meet in the CM and there are gains from trade, they bargain over the price. The price is in terms of money, by which we do not necessarily mean cash but liquid assets generally, which by definition are assets that can be accessed from the DM.[8] If the price p at which they would trade in the absence of liquidity considerations is greater than the assets e happens to have available, several things could happen: i could keep I for himself; he could settle for a lower price; or they could try to meet again in the next CM, where e can always raise the funds. However, if they try to meet again, with probability $1-\gamma$ they fail. Rather than take a particular stand on why this might happen, we simply label the event an exogenous breakdown, as is common in bargaining theory; or, we say *the deal falls through.*

This possibility is what generates a demand for liquidity. Clearly, we need imperfect enforcement of credit for this to work, since otherwise e could offer i an IOU. The easiest assumption to rule this out is to say that e can simply renege without fear of repercussions; then i will never give

[8]For instance, in a related albeit simpler model, He et al. (2005) allow agents to use interest-bearing checking accounts for payments in the DM. We could do something similar here, but for focus, we want to avoid these details. Although our notation and some of our assumptions are suggestive of money and monetary theory, hopefully it is understood that the general point applies to liquid assets more broadly.

up his idea on a promise.[9] Also, we understand that there are of course many ways in the real world for innovators to get people who are good at implementation involved in their projects, including hiring them, forming partnerships, licensing, etc. We focus the case where they *sell* the idea. While this is not the only possibility it is surely an interesting one. Among other reasons, it captures the notion that innovators prefer not to be involved in actual operations so that they can concentrate on coming up with new ideas (again see *The Economist* Oct. 2005).

3 The CM

Let $W_j(m, R)$ be the the value functions for type $j = i, e$ agents entering the CM, with liquid assets m and a project in hand with value R (for i this would be his own idea if he did not sell it in the previous DM, and for e this would be an idea that he purchased). We use $R = 0$ to indicate either a project with 0 return, or no project (for i this would be because he sold his idea, and for e this would be because he failed to buy one). Let $V_j(m)$ be the value function for agents entering the DM with m dollars before the random values of ideas are drawn.

Then for $j = i, e$ the CM problem is

$$\begin{aligned} W_j(m, R) &= \max_{X,H,\hat{m}} \{U(X) - h + \delta V_j(\hat{m})\} \qquad (2) \\ \text{s.t. } X &= X_0 + wh + \phi(m - \hat{m} + \pi M) + R, \end{aligned}$$

[9] It is important for this that we cannot use reputation to enforce payment. One common way in monetary theory to rule this out formally is to assume some form of anonymity; see e.g. Kocherlakota (1998), Wallace (2001) or Corbae et al. (2003).

where X is consumption, h is labor supply, $\hat{m}$ is liquidity taken out of the CM, X_0 is an endowment, w is the real wage, and ϕ is the relative price of liquid assets in term of X. The term πM is a lump sum increase in one's liquid assets, with M denoting the aggregate stock at the start of CM. Thus it evolves over time according to $M' = (1+\pi)M$, as in models where M is interpreted as central bank money. Although the theory is meant to apply to liquid assets generally, we adopt this specification for M simply because it is a convenient way to parameterize the cost of liquidity: in steady state π will be the inflation rate in terms of the liquid asset, and interest rates will satisfy the Fisher equation (see below).

Assume for now that there is a representative firm with a linear technology, so the equilibrium wage is pinned down and can be normalized to $w = 1$; in Section 6.4 we show how to incorporate a more general labor market. Then, rewrite (2) as

$$\begin{aligned} W_j(m, R) &= X_0 + \phi m + \phi \pi M + R + \max_X \{U(X) - X\} \\ &\quad + \max_{\hat{m}} \{-\phi \hat{m} + \delta V_j(\hat{m})\}. \end{aligned} \tag{3}$$

Assuming an interior solution, which can be guaranteed by adapting some assumptions in Lagos and Wright (2005), as well as the strict concavity of V_j, which we verify below, the following results are immediate:

Lemma 1 *(i) W_j is linear in (m, R), with $\partial W_j/\partial m = \phi$ and $\partial W_j/\partial R = 1$; (ii) X is given by the solution to $\partial U(X)/\partial X = 1$; (iii) $\hat{m}$ is given by the solution to*

$$-\phi + \delta \frac{\partial V_j(\hat{m})}{\partial \hat{m}} \leq 0, = 0 \text{ if } \hat{m} > 0, \tag{4}$$

and in particular, all agents of a given type j take the same $\hat{m}_j$ out of the CM, regardless of the (m, R) with which they enter.

4 The DM

Let α_j be the DM arrival rate (probability of a meeting) for $j = i, e$. Normalizing the measure of entrepreneurs to $N_e = 1$, the only restriction on arrival rates is $\alpha_e = \alpha_i N_i$, so we can take α_j to be exogenous, at least for now. If an e does not meet anyone, he enters the next CM with his money but no project, $(\hat{m}_e, 0)$. Similarly, if i does not meet anyone, he enters the next CM with $(\hat{m}_i, R_i)$. If an e and i do happen to meet, several things can happen. If $R_e \leq R_i$ there are no gains from trade and they simply part; if $R_e > R_i$ there are gains from trade, and two cases need to be considered.

On the one hand, suppose $\hat{m}_e \geq p$, where p is the price they would agree to if there were no issues of liquidity – e.g. if e had access to the funds he will have available in the next CM, from his endowment and/or labor supply. Then they can – an in equilibrium they will – trade immediately at price p. On the other hand, suppose $\hat{m}_e < p$. In this case the bargaining problem is nonconvex, and in principle they may want to trade using lotteries. However, for simplicity we assume in this section that lotteries are not available, and revisit the issue in Section 6.2 where we show that the main economic results are similar. Hence, for now they can either settle for $\hat{m}_e$, or put the deal on hold and try to meet again in the next CM, where e can always raise the funds. If they do meet again they can renegotiate the price to p', but we will see that $p' = p$. In any case, meeting again in the next CM only happens with probability γ; otherwise the deal falls through. The big question for i is this: should he settle for $\hat{m}_e$ and close the deal right now, or put it on hold for a chance at p'?

We now analyze the bargaining problems in more detail. We use the generalized Nash solution, where threat points are given by continuation values and θ denotes the bargaining power of e. To begin, consider what happens if they put the deal on hold and meet again in the next CM. Given the value function next period W'_j, the bargaining solution is:

$$\max_{p'}[W'_e(\hat{m}_e - p', R_e) - W'_e(\hat{m}_e, 0)]^{\theta}[W'_i(\hat{m}_i + p', 0) - W'_i(\hat{m}_i, R_i)]^{1-\theta}$$

By Lemma 1, $W'_e(\hat{m}_e - p', R_e) - W'_e(\hat{m}_e, 0) = R_e - \phi' p'$ and $W'_i(\hat{m}_i + p', 0) - W'_i(\hat{m}_i, R_i) = \phi' p' - R_i$, so this reduces to $\max_{p'} \left(R_e - \phi' p'\right)^{\theta} \left(\phi' p' - R_i\right)^{1-\theta}$ and yields

$$p' = \frac{\theta R_i + (1-\theta) R_e}{\phi'}. \tag{5}$$

Now, move back to this period and consider what happens in the current DM. One difference from CM bargaining is that the threat points are given by the expected values of putting the deal on hold,

$$\begin{aligned}
\overline{W}'_e &= \gamma W'_e(\hat{m}_e - p', R_e) + (1-\gamma) W'_e(\hat{m}_e, 0) \\
\overline{W}'_i &= \gamma W'_i(\hat{m}_i + p', 0) + (1-\gamma) W'_i(\hat{m}_i, R_i).
\end{aligned}$$

A second difference is that we have a constraint $p \leq \hat{m}_e$, since e can only pay out of liquid assets in the DM (by definition). The problem becomes:

$$\max_{p \leq \hat{m}_e} [-\phi' p + \gamma \phi' p' + (1-\gamma) R_e]^{\theta} [\phi' p - \gamma \phi' p' - (1-\gamma) R_i]^{1-\theta}$$

Suppose first the constraint does not bind. Then it is simple to show $p = p'$, the same as the solution in the next CM. In this case they settle immediately. Suppose instead that $\hat{m}_e < p'$, which is equivalent to $R_e > B(R_i) \equiv \frac{\phi' \hat{m}_e - \theta R_i}{1-\theta}$ (the label B stands for the fact that the liquidity constraint *binds*). In this case e always wants to pay $\hat{m}_e$ and close the deal now, but i puts the deal on hold iff $W_i'(\hat{m}_i + \hat{m}_e, 0) < \overline{W}_i'$, which simplifies to $R_e > H(R_i) \equiv \frac{\phi' \hat{m}_e - R_i(1-\gamma+\theta\gamma)}{\gamma(1-\theta)}$ (the label H stands for the fact that he is prefers putting the deal on *hold*).

We summarize the bargaining outcome in Lemma 2, the proof of which follows directly from the above discussion, and illustrate it in Figure 1, taking $z = \phi' \hat{m}_e$ as given (it will be determined in equilibrium below).

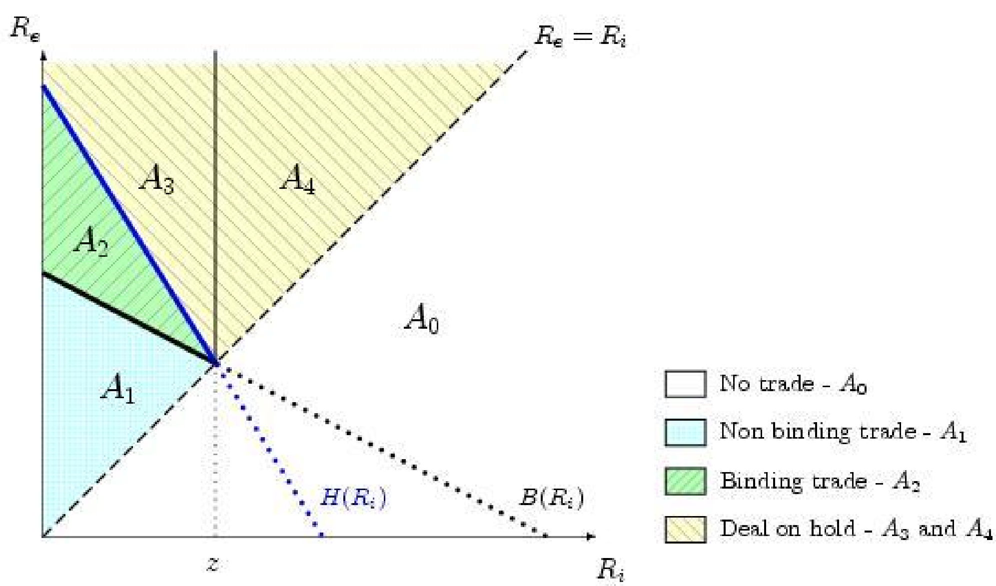


Figure 1: Possible realizations of (Ri, Re).

Lemma 2 *Assume $R_e > R_i$. In the DM, if $R_e \leq B(R_i)$ they trade now at $p = p'$, given by (5); if $B(R_i) < R_e \leq H(R_i)$ they trade now at $p = \hat{m}_e$; and if $R_e > H(R_i)$ the deal is put on hold. In the CM, they trade at p'.*

One thing to notice from these results is that it is the *best* deals that are put on hold and hence potentially fall through. Intuitively, when R_e is high the CM price p' is high, so i has a big incentive to put a deal on hold. At the same time, when R_i is high there is less downside risk, which also provides incentive to put a deal on hold.

Given the bargaining solution, we now proceed to the DM value function. For e, this is given by

$$\begin{aligned} V_e(\hat{m}) &= (1-\alpha_e)\beta W_e'(\hat{m},0) + \alpha_e\beta \int\limits_{A_0} W_e'(\hat{m},0) \qquad (6) \\ &\quad + \alpha_e\beta \int\limits_{A_1} W_e'(\hat{m}-p,R_e) + \alpha_e\beta \int\limits_{A_2} W_e'(0,R_e) + \alpha_e\beta \int\limits_{A_3\cup A_4} \overline{W}_e' \end{aligned}$$

where $\int_{A_j}(\cdot)$ is the integral over region A_j in Figure 1; e.g.

$$\int\limits_{A_1}(\cdot) = \int\limits_0^z \int\limits_{R_i}^{B(R_i)} (\cdot) dF_e(R_e|R_i) dF_i(R_i).$$

In words, the first term in (6) is the payoff to no meeting; the second is the payoff to a meeting with no trade; the third is the payoff to trading at $p = [\theta R_i + (1-\theta)R_e]/\phi'$; the fourth is the payoff to trading at $p = \hat{m}$; and the fifth is the payoff to a deal on hold.[10] Using the linearity of W_e' (Lemma

[10] We distinguish between A_3 and A_4, even though in both regions deals are put on hold, because the economic interpretation is different. In A_4, even if e were to give i all his money, i is better off keeping I since $R_i > \hat{m}_e\phi'$. In A_3, i prefers trading for $\hat{m}_e$ over implementing I himself, but he prefers putting the deal on hold for a chance at p'.

1) and inserting p, we can simplify (6) to

$$V_e(\hat{m}) = \beta W_e'(\hat{m},0) + \alpha_e\beta\theta \int_{A_1} (R_e - R_i) + \alpha_e\beta \int_{A_2} (R_e - \phi'\hat{m}) + \gamma\alpha_e\beta\theta \int_{A_3 \cup A_4} (R_e - R_i). \tag{7}$$

A similar exercise can be performed for i, and it turns out that

$$V_i(\hat{m}) = \beta\phi'\hat{m} + v, \tag{8}$$

where v is a constant that does not depend on $\hat{m}$. Intuitively, for i neither the probability of trade nor the terms of trade depend on his own liquidity – indeed, they depend only on liquidity on the other side of the market. Therefore, any $\hat{m}$ he brings to the DM will simply be carried forward to the next CM.

We also need the derivatives. For i, this is trivially $\partial V_i/\partial\hat{m} = \beta\phi'$. For e, we establish in Appendix A the following result, which is somewhat complicated because we have to consider several cases to avoid dividing by 0.

Lemma 3 *$\partial V_e/\partial\hat{m} = \beta\phi'\left[1 + \ell(\phi'\hat{m})\right]$, where for any z, $\ell(z)$ is defined as follows: (i) if $\gamma > 0$ and $\theta < 1$ then*

$$\ell(z) = \frac{\alpha_e(1-\gamma)}{\gamma^2(1-\theta)^2} \int_0^z (z - R_i)\, F_e'\left[H(R_i)|R_i\right] dF_i(R_i) - \alpha_e \int_0^z \left\{F_e\left[H(R_i)|R_i\right] - F_e\left[B(R_i)|R_i\right]\right\} dF_i(R_i); \tag{9}$$

(ii) if $\gamma = 0$ and $\theta < 1$ then

$$\ell(z) = \alpha_e F_i'(z) \int_z^\infty (R_e - z) dF_e(R_e|z) - \alpha_e \int_0^z \{1 - F_e[B(R_i)|R_i]\} dF_i(R_i); \tag{10}$$

(iii) if $\theta = 1$ then

$$\ell(z) = (1-\gamma)\alpha_e F_i'(z) \int_z^\infty (R_e - z) dF_e(R_e|z). \tag{11}$$

Notice $\ell(z)$ is the net marginal benefit of liquidity. Consider e.g. the case $\gamma = 0$. The first term in (10) is the probability of meeting i with $R_i = z$, $\alpha_e F_i'(z)$, times the net gain for e, $R_e - z$, integrated over R_e. The second term is the probability of $(R_i, R_e) \in A_2$ times -1, since in A_2 the constraint binds and the marginal dollar is simply handed over to i.[11]

5 Equilibrium

We now combine the DM and CM and define equilibrium. The key condition from the CM is the FOC for $\hat{m}$, given by (4). All we need to do is insert the derivative of the DM value function. For $j = i$ this is easy: by (8), $\partial V_i / \partial \hat{m} = \beta \phi'$, so (4) becomes $-\phi + \delta\beta\phi' \leq 0, = 0$ if $\hat{m} > 0$. As is standard, we only consider equilibria where $\delta\beta\phi' < \phi$, because when $\delta\beta\phi' > \phi$ no equilibrium exists and when $\delta\beta\phi' = \phi$ equilibrium is indeterminate. Given $\delta\beta\phi' < \phi$, we have $\hat{m}_i = 0$.

[11] Notice $\partial V_e / \partial \hat{m} = [1 + \ell(z)] \partial V_i / \partial \hat{m}$, which says for e the return on $\hat{m}$ includes a liquidity component that is not there for i. See Lagos (2005) for an discussion of similar equations in a related model of liquidity and asset pricing.

To understand this, consider the Fisher equation $1 + i_n = (1 + i_r)\phi/\phi'$, where i_n is the nominal interest rate, i_r is the real interest rate, and ϕ/ϕ' is the inflation rate in terms of the price of liquid assets between two CM meetings. In this model $1+i_r = 1/\beta\delta$, so $\delta\beta\phi' < \phi$ is equivalent to $i_n > 0$. To restate what we said above in terms of interest rates, $i_n < 0$ is inconsistent with equilibrium and $i_n = 0$ implies equilibrium is indeterminate. Hence, we restrict attention to the case where liquidity is costly, which means $i_n > 0$, although we also consider the limiting case where $i_n \to 0$. Since i does not need liquidity, given it is costly, $\hat{m}_i = 0$.

A similar exercise for $j = e$ is more interesting. By Lemma 3, we have

$$-\phi + \delta\beta\phi' \left[1 + \ell(\phi'\hat{m})\right] \leq 0, = 0 \text{ if } \hat{m} > 0. \tag{12}$$

Given $\hat{m}_i = 0$ and $N_e = 1$, we could now set $\hat{m}_e$ to the exogenous supply M of liquid assets, and equilibrium could be defined in terms of a path for ϕ satisfying (12), plus some side conditions. But to simplify the discussion we focus on steady state equilibria, where $z = \phi M$ is constant. Again using the Fisher equation, in steady state (12) becomes[12]

$$\ell(z) \leq i_n, \ = i_n \text{ if } z > 0. \tag{13}$$

Consider first the generic case $\gamma \in (0, 1)$ and $\theta \in (0, 1)$. Since $\ell(0) = 0$, an equilibrium with $z = 0$ always exists. Since this is not interesting, from now on we ignore it and concentrate on solutions to $\ell(z) = i_n$ with $z > 0$.

[12] We emphasize that i_n is an exogenous variable here, and, because of the Fisher equation, we can either set i_n directly and let the growth rate of M adjust, or set π to target i_n.

We also require $\ell'(z) = \partial^2 V_e/\partial\hat{m}^2 \leq 0$, which is necessary and sufficient for the SOC to hold in problem (3). Thus we have:

Definition 1 *An equilibrium is a $z > 0$ such that $\ell(z) = i_n$ and $\ell'(z) \leq 0$.*

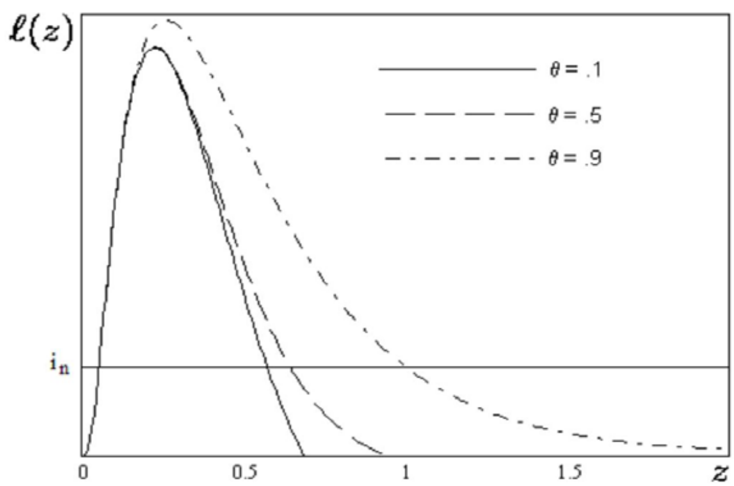


Figure 2: $\ell(z)$ for independent lognormal distributions.

Given $\gamma \in (0,1)$ and $\theta \in (0,1)$, Appendix B shows that $\lim_{z\to\infty} \ell(z) = 0$, and that one can impose simple conditions such as F_j' continuous to guarantee that ℓ is continuous and $\ell(z) > 0$ for some $z > 0$. Then clearly there exists a solution to $\ell(z) = i_n$ iff i_n is not too big, and these solutions generically come in pairs. For each pair of solutions, the higher z constitutes an equilibrium, while the lower z does not because it violates $\ell'(z) \leq 0$. Figures 2 and 3 show two examples that illustrate the typical case. The general result, the proof of which follows from the above discussion and the technical results in Appendix B, is basically the same:

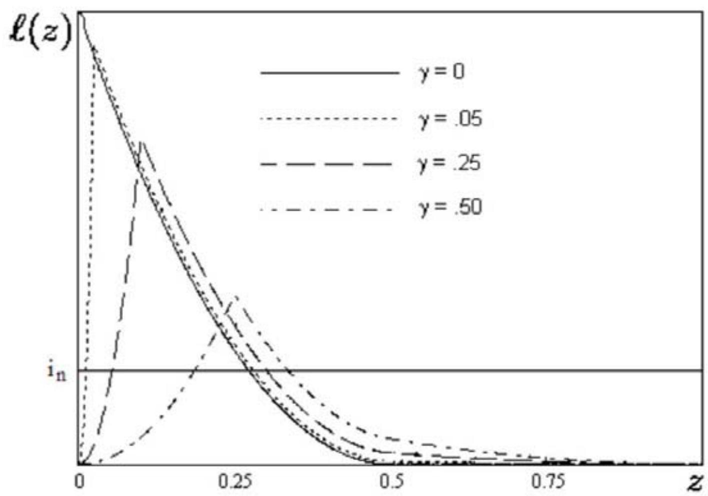


Figure 3: $\ell(z)$ for independent uniform distributions.

Proposition 1 *Given $\gamma \in (0,1)$, $\theta \in (0,1)$ and ℓ continuous, there exists an equilibrium $z > 0$ iff i_n is not too big.*

For completeness, we discuss what happens when we do not have $\gamma \in (0,1)$ and $\theta \in (0,1)$. If $\theta = 1$ or $\gamma = 0$, the results are the same but for minor details.[13] If $\gamma = 1$, however, things are very different, since then $\ell(z) = 0$ for all z and there is no equilibrium with $z > 0$. This is because $\gamma = 1$ implies e can always raise funds in the CM without fear that a deal may fall through, so he has no demand for liquidity. Finally, we mention that even if $\theta = 0$ it is still possible to have equilibrium with $z > 0$, which is *not* true in related models.[14]

[13] In this case we may have $\ell(0) > 0$, but this is irrelevant for the economics. If $\ell(0) > 0$, we may lose the first solution to $\ell(z) = i_n$, but in any case it violates $\ell'(z) \leq 0$.

[14] In Lagos and Wright (2005) e.g., if $\theta = 0$ then e gets no gains from trade, and $\hat{m}_e = 0$. Here e still gets positive gains from trade in A_2 even if $\theta = 0$, because I is indivisible (this will *not* be the case when we introduce lotteries in Section 6.2).

In any equilibrium, when $R_e > R_i$ there are gains from trade, but if $\gamma < 1$ then not every deal can get done in the CM. If a deal is put on hold, with probability $1 - \gamma$ it falls through. If z is bigger, it is more likely that deals get done in the DM and less likely that they fall through. The following obvious result then says that when i_n is lower, it is less likely that deals fall through, and therefore the best outcome obtains in the limit when i_n is as small as possible.

Proposition 2 *(i) $\partial z / \partial i_n \leq 0$; (ii) z is maximized and the number of deals that fall through is minimized when $i_n \to 0$.*

To the extent that policy makers have an impact on the cost of liquidity, this points to a new and potentially important channel through which policy may matter. It is potentially important because it highlights the idea that liquidity (money?) may not only be needed for small purchases, like cigarettes and taxi rides, but perhaps also for bigger things, and recall that it is the biggest deals that are in the greatest danger of falling through. If i_n goes up and agents economize on $\hat{m}$, this not only leads to less smoking and more walking, but also to less efficient technology transfer, and due to spill-over effects (discussed in the next section) this can have important general equilibrium effects.

Even though the limiting case $i_n \to 0$ maximizes trade, it does *not* generally entail full efficiency. The efficient outcome is for e to have sufficient liquidity to close the deal in the DM with probability 1 whenever $R_e > R_i$. When $i_n \to 0$ we minimize the probability that deals fall through, but for efficiency generally we also need $\theta = 1$. This is easy to see from Figure 2 which makes it clear that when $\theta < 1$ the equilibrium z generally does not allow e to close all profitable deals, and from (11) which makes it clear that $\theta = 1$ does yield full efficiency when $i_n \to 0$. This is due to a classic holdup problem: when e chooses $\hat{m}_e$ he makes an investment, but as long as $\theta < 1$ he does not get the full return, which causes him to underinvest.

Proposition 3 *Equilibrium is efficient iff* $i_n = 0$ *and* $\theta = 1$.

6 Extensions

6.1 One-Sided Uncertainty

Consider the model with $R_i = \bar{R}$ with probability 1, so I is always the same for i, but the value to e is still random; because this reduces the algebra somewhat, it may be useful in applications or extensions. It is easy to check now that there is no equilibrium with $z \in (0, \bar{R})$, so consider $z \geq \bar{R}$. It is relatively simple in this special case to redo the general analysis to directly derive

$$\begin{aligned} V_e(\hat{m}) &= \beta W_e'(\hat{m}, 0) + \alpha_e \beta \theta \int_{\bar{R}}^{B(\bar{R})} (R_e - \bar{R}) dF_e(R_e) \\ &\quad + \alpha_e \beta \int_{B(\bar{R})}^{H(\bar{R})} (R_e - \phi' \hat{m}) dF_e(R_e) + \alpha_e \beta \gamma \theta \int_{H(\bar{R})}^{\infty} (R_e - \bar{R}) dF_e(R_e), \end{aligned}$$

and

$$\ell(z) = \frac{\alpha_e (1-\gamma)(z - \bar{R})}{\gamma^2 (1-\theta)^2} F_e' \left[H(\bar{R}) \right] - \alpha_e \left\{ F_e \left[H(\bar{R}) \right] - F_e \left[B(\bar{R}) \right] \right\}.$$

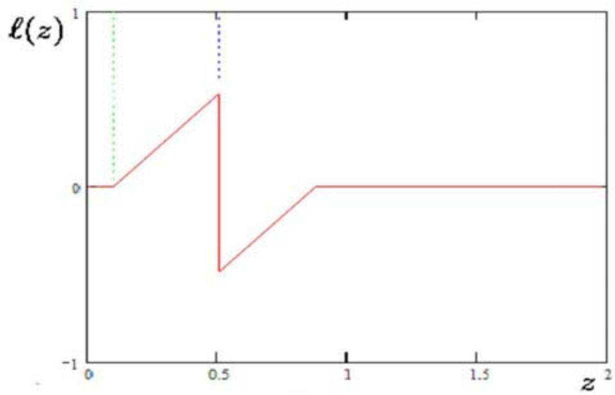


Figure 4: $\ell(z)$ for R_e uniform and R_i degenerate.

Suppose e.g. R_e is uniform on $[0,1]$. Then

$$\ell(z) = \begin{cases} 0 & z < \bar{R} \\ \frac{\alpha_e(1-\gamma)(1-\gamma+\gamma\theta)(z-\bar{R})}{\gamma^2(1-\theta)^2} & \bar{R} < z < z_H \\ \frac{\alpha_e(z-\theta\bar{R}-1+\theta)}{1-\theta} & z_H < \bar{R} < z_B \\ 0 & \bar{R} > z_B \end{cases}$$

where $z_H = \gamma(1-\theta)+(1-\gamma+\gamma\theta)\bar{R}$ and $z_B = 1-\theta+\theta\bar{R}$. As seen in Figure 4, $\ell(z)$ is piece-wise linear with a discontinuity at z_H, and for any i_n below some upper bound $\hat{\imath}_n$ there is a unique equilibrium at $z = z_H$.[15] This example is nice because we can solve for everything explicitly, but it does have the property that the equilibrium z is (locally) insensitive to i_n. Figure 5 shows an example with R_e log-normal, which does not yield a closed-form solution, but it is easy to see that $\ell(z)$ is continuous and z smoothly decreases with i_n.

[15] The discontinuity here is not a problem for existence: at $z = z_H - \varepsilon$ the marginal value of additional liquidity exceeds i_n, and at $z = z_H + \varepsilon$ marginal value is actually negative, so e chooses $z = z_H$. For the record, the upper bound is $\hat{\imath}_n = \alpha_e(1-\gamma)(1-\theta+\theta\gamma)(1-\bar{R})/\gamma(1-\theta)$.

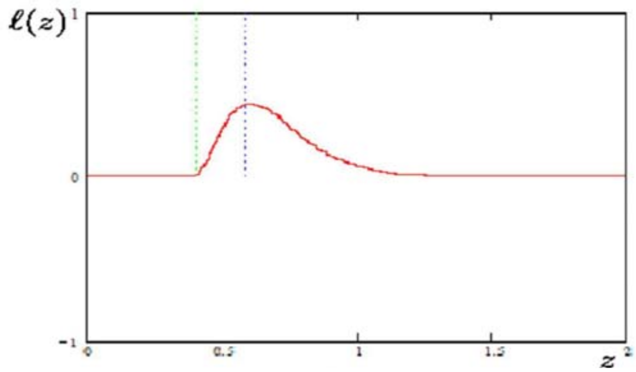


Figure 5: $\ell(z)$ for R_e lognormal and R_i degenerate.

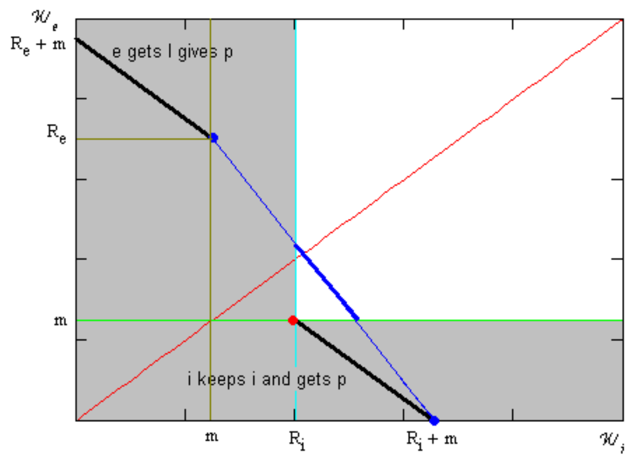
6.2 Lotteries

When I is indivisible and $p \leq \hat{m}_e$ binds, the bargaining problem can be nonconvex, and agents may want to use lotteries.[16] To see this, consider the one-shot version of the model shown in Figure 6, with two panels drawn for different values of R_i. No trade yields payoffs $(\mathcal{W}_i, \mathcal{W}_e) = (R_i, m)$, so the non-shaded region constitutes the incentive feasible region. Options that do not throw resources away and satisfy physical, if not incentive, feasibility are: for any $p \in [0, m]$, $(\mathcal{W}_i, \mathcal{W}_e) = (p, R_e + m - p)$, which means e gets I and gives up p units of m, as depicted by the lines with slope -1 on the upper left, and $(\mathcal{W}_i, \mathcal{W}_e) = (R_i + p, m - p)$, which means i keeps I but still gets p, as depicted by the lines with slope -1 on the lower right.

In the upper panel, since R_i is big, without lotteries there are no incentive feasible points that dominate no trade; but lotteries that randomize between

[16] Nonconvex Nash-like bargaining is studied by e.g. Herrero (1989). Our approach of using lotteries, which makes the problem convex, follows Berentsen et al. (2002), although they only consider a very special case.

(m, R_e) and $(R_i+m, 0)$ yield expected payoffs on the line joining these points, and some of these points dominate no trade. In the lower panel, where R_i is smaller, there are some incentive feasible points that dominate no trade without lotteries; but randomization allows us to achieve more outcomes still. Based on this, it should be clear that in general there is a role for lotteries in nonconvex bargaining situations.



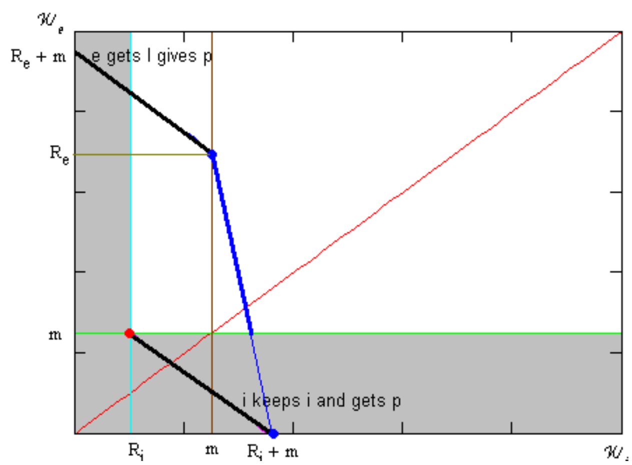


Figure 6: Possibility of Lotteries

Appendix C shows that lotteries are never used in the CM (even if I is indivisible, when there is no liquidity constraint the problem is convex). Lotteries are only useful in the DM when the constraint $p \leq \hat{m}_e$ binds. Appendix C also shows that deals are never put on hold directly when we have lotteries: if the constraint binds, first there is a deal where e gives i all his liquid assets $\hat{m}_e$ in exchange for a probability $\mu \in (0,1)$ of transferring I. If e does not win this lottery he does not get I, but they still might meet in the next CM, where as always e can and does get it for p'. Thus, e potentially pays twice: once for the lottery, and if that does not pan out, again in the CM if they manage to meet. Whether or not this is "realistic" we want to know how it works.

The payoff for e from the lottery is

$$\mu W_e'(\hat{m}_e - p, R_e) + (1-\mu)[\gamma W_e'(\hat{m}_e - p - p', R_e) + (1-\gamma) W_e'(\hat{m}_e - p, 0)]$$

and his threat point is $\gamma W_e'(\hat{m}_e - p', R_e) + (1-\gamma) W_e'(\hat{m}_e, 0)$, and similarly for i. Simplifying using the linearity of W_j, the bargaining problem is:

$$\max_{p \leq \hat{m}_e, \mu \leq 1} \left[-\phi' p + \mu(1-\gamma) R_e + \mu\gamma\phi' p'\right]^{\theta} \left[\phi' p - \mu(1-\gamma) R_i - \mu\gamma\phi' p'\right]^{1-\theta}$$

Nonnegativity never binds, but we need to worry about the constraints $p \leq \hat{m}_e$ and $\mu \leq 1$. If these are both nonbinding, the FOC wrt p and μ are:

$$\begin{aligned} 0 &= \theta \left[\phi' p - \mu(1-\gamma) R_i - \mu\gamma\phi' p'\right] \\ &\quad -(1-\theta)\left[-\phi' p + \mu(1-\gamma) R_e + \mu\gamma\phi' p'\right] \end{aligned} \tag{14}$$

$$\begin{aligned} 0 &= \theta \left[\phi' p - \mu(1-\gamma) R_i - \mu\gamma\phi' p'\right]\left[(1-\gamma) R_e + \gamma\phi' p'\right] \\ &\quad -(1-\theta)\left[-\phi' p + \mu(1-\gamma) R_e + \mu\gamma\phi' p'\right]\left[(1-\gamma) R_e + \gamma\phi' p'\right] \end{aligned} \tag{15}$$

Notice that these cannot both hold when $R_e > R_i$; hence we cannot have both $p < \hat{m}_e$ and $\mu < 1$. If $\mu = 1$ and $p < \hat{m}_e$ then (14) implies $p = p'$. If $p = \hat{m}_e$ and $\mu < 1$ then (15) implies $\mu = \Omega\phi'\hat{m}_e$, where

$$\Omega = \frac{(\theta + \gamma - 2\gamma\theta)R_e + (1 - \theta - \gamma + 2\gamma\theta)R_i}{[(1 - \theta\gamma)R_e + \gamma\theta R_i][\gamma(1 - \theta)R_e + (1 - \gamma + \theta\gamma)R_i]}.$$

Appendix C verifies that $\partial\Omega/\partial R_i < 0$ and $\partial\Omega/\partial R_e < 0$, and that $\mu = \Omega\phi'\hat{m}_e < 1$ iff $R_e > B(R_i)$, where B is the same as in the model without lotteries. Appendix C also shows that $\partial\mu/\partial\theta > 0$ and $\partial\mu/\partial\gamma < 0$.

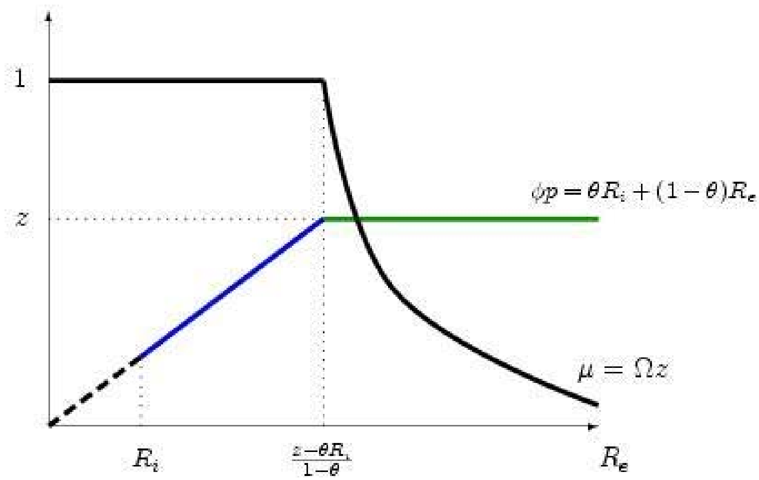


Figure 7: Lottery outcomes given z and R_i.

All of this implies that the outcome is as depicted in Figure 7, which shows the bargaining solution (p, μ) as a function of R_e for a given R_i. As R_e increases, p increases while μ stays at 1 until p hits $\hat{m}_e$, after which μ decreases while p stays at $\hat{m}_e$. The main impact of introducing lotteries is to allow immediate trade to potentially occur in what was region $A_3 \cup A_4$, where the deal previously was put on hold. However, the lottery only allows the idea to be transferred with probability μ in the DM. There is still a chance it falls through. Also, it is still the best deals that have the greatest risk of falling through.[17]

6.3 Nonrival Ideas

In general, if i transfers I to e the returns are $\lambda_i R_i$ and $\lambda_e R_e$, but so far we assumed $\lambda_i = 0$ and $\lambda_e = 1$. Here we consider the general case. In terms of interpretation, suppose i gives e an idea for a restaurant, and they both open for business. Then instead of receiving the full return either would get if he were a monopolist, they receive only a fraction when they compete. Now there are gains from trade whenever $\lambda_e R_e > (1 - \lambda_i) R_i$.

The CM bargaining problem is

$$\max_{p'} [\lambda_e R_e - \phi p]^{\theta} [\phi p' - (1 - \lambda_i) R_i]^{1-\theta}$$

which implies $\phi p' = \theta (1 - \lambda_i) R_i + (1 - \theta) \lambda_e R_e$. The DM problem is

$$\max_{p \leq m_e} [-\phi p + \gamma \phi p' + (1 - \gamma) \lambda_e R_e]^{\theta} [\phi p - \gamma \phi p' - (1 - \gamma)(1 - \lambda_i) R_i]^{1-\theta}$$

[17] Indeed, notice $\mu \to 0$ as $R_e \to \infty$. Also, for the record, the liquidity function when $\gamma > 0$ and $\theta < 1$ is:

$$\begin{aligned} \ell(z) \equiv{}& \frac{\alpha_e \theta (1-\gamma)}{(1-\theta)^2} \int_0^z \tfrac{[z\gamma + R_i(1-\gamma) - 1](z - R_i)}{z\gamma + R_i(1-\gamma)} F_e' \left[B(R_i) | R_i \right] dF_i(R_i) \\ & + \alpha_e \theta (1-\gamma) \left\{ \int_0^z \int_{B(R_i)}^{\infty} \tfrac{(R_e - R_i) dF_e \ (R_e | R_i) dF_i(R_i)}{(1-\theta)\gamma R_e + (1 - \gamma + \theta\gamma) R_i} + \int_z^{\infty} \int_{R_i}^{\infty} \tfrac{(R_e - R_i) dF_e \ (R_e | R_i) dF_i(R_i)}{(1-\theta)\gamma R_e + (1 - \gamma + \theta\gamma) R_i} \right\} \end{aligned}$$

and, as in the baseline model, if the constraint does not bind the solution is $p = p'$. The constraint binds iff $R_e > B(R_i) = \frac{\phi m - \theta(1-\lambda_i)R_i}{(1-\theta)\lambda_e}$, and the deal is put on hold iff $R_e > H(R_i) = \frac{\phi m - R_i(1-\lambda_i)(1-\gamma+\gamma\theta)}{\gamma(1-\theta)\lambda_e}$, generalizing what we had earlier. See Figure 8.[18]

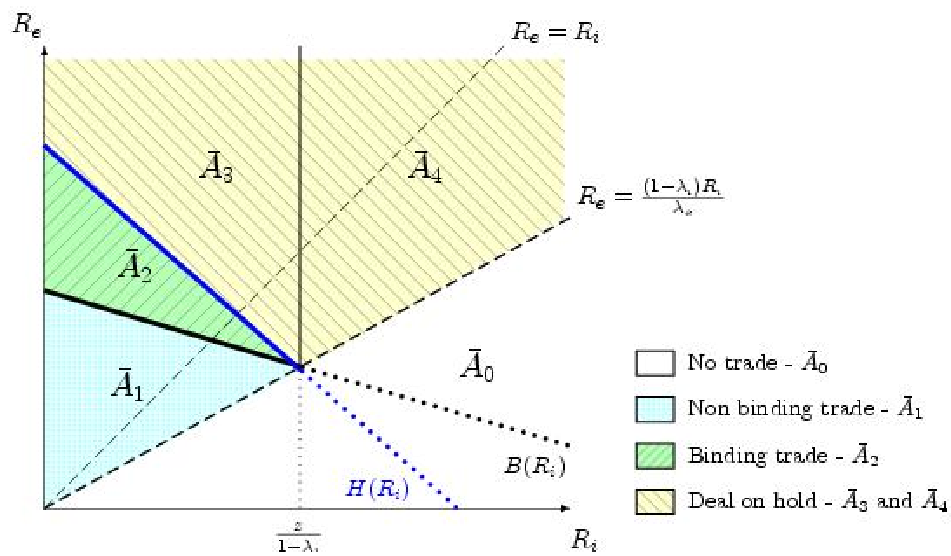


Figure 8: Possible realizations for (R_i, R_e) in model with $1 - \lambda_i < \lambda_e$.

In the baseline model, if a deal falls through the social loss is $R_e - R_i$, but here it is $\lambda_e R_e + \lambda_i R_i - R_i$. At the extreme, if I is a pure public good

[18] In the limiting case where $\lambda_i = 1$, A_0 vanishes since all trade is profitable, and B and H become horizontal. For the record, when $\gamma > 0$ and $\theta < 1$,

$$\begin{aligned} \ell(z) \equiv \; & \frac{(1-\gamma)\alpha_e}{\gamma^2(1-\theta)^2\lambda_e} \int_0^{\frac{z}{1-\lambda_i}} [z - (1-\lambda_i)R_i]\, F_e'[H(R_i)|R_i]\, dF_i(R_i) \\ & -\alpha_e \int_0^{\frac{z}{1-\lambda_i}} \{F_e[H(R_i)|R_i] - F_e[B(R_i)|R_i]\}\, dF_i(R_i). \end{aligned}$$

($\lambda_i = \lambda_e = 1$) the social loss is R_e. Thus the potential benefit from having the idea market function relatively smoothly – say, because γ is relatively high or i_n relatively low – is bigger when there is a public component to ideas, and the impact of policy may be even greater than the discussion following Proposition 2 would suggest.

6.4 Ideas as Intermediate Inputs

Here we return to the specification in (1), $R_j(I) = \max_{\mathbf{h}} \{f_j(\mathbf{h}, I) - \mathbf{wh}\}$ where $\mathbf{h}$ is a vector of inputs and $\mathbf{w}$ a vector of prices. Since it suffices to make the point, suppose that the only input other than I is labor, so that we can write $\mathbf{h} = h$ and $\mathbf{w} = w$. From the FOC $f_j'(h, I) = w$, as long as $f_j'(h, I)$ is increasing in I, a better match between I and j increases the maximizing choice of h. Hence, anything that improves the functioning of the idea market – again, higher γ or lower i_n e.g. – increases labor demand.

Since we have a general equilibrium model we also need to consider labor supply. From the CM budget equation, for individual j in state (m, R),

$$h_j(m, R) = \frac{1}{w}\left[X - X_0 - \phi(m - \hat{m}_j + \pi M) - R\right].$$

Hence, individual labor supply depends on (m, R) as well as w. Aggregating and using money market clearing,

$$H(w) = \int_j h_j(m, R) = \frac{1}{w}\left[X(w) - X_0 - ER\right],$$

where $X(w)$ solves $U'(X) = 1/w$. Notice $X'(w) = -1/w^2 U'' > 0$, and

$$H'(w) = \frac{wX'(w) - X(w)}{w^2} \simeq -1 - XU''/U',$$

where $\simeq$ means "is equal in sign." Thus, $H'(w) > 0$ iff the coefficient of relative risk aversion exceeds 1, which we assume for the purpose of this discussion.

Observe that H is decreasing in ER, since higher ER means agents do not have to work as hard to finance X. Therefore, anything that makes the DM function better reduces labor supply (a pure wealth effect), at the same time it increases demand. The net effect is to unambiguously increase the equilibrium wage w and consumption $X(w)$, while employment could go either way. The general point is that anything that affects the market for ideas can have potentially important general equilibrium consequences.[19]

6.5 Endogenous γ

Suppose e can choose his γ, in the CM, at the same time as he chooses $\hat{m}$. On the one hand, having γ big is desirable because then fewer profitable deals fall through. On the other hand, having γ small has the advantage that it makes i reluctant to put deals on hold, and hence e may get the idea for $\hat{m}$ rather than p'. We look for symmetric equilibrium in the game where e chooses $(\hat{\gamma}, \hat{m})$. To make the point in a stark way, assume that e can choose any $\hat{\gamma} \in [0, 1]$ *for free*, and can commit to this choice. Then it is easy to check that there is always an equilibrium with $(\hat{\gamma}, \hat{m}) = (1, 0)$; what we want to investigate is the possibility of equilibrium with $\gamma < 1$, even though

[19] An alternative version of the model that is equivalent for most purposes but simpler for this extension is to assume utility is linear in X rather than h: $U = X - v(h)$, with $v' > 0$ and $v'' > 0$. This yields the same FOC for $\hat{m}$, but now $H(w)$ solves $w = v'(h)$, so $H'(w) = 1/v'' > 0$. Hence labor supply is increasing in w and independent of wealth. In this model, any improvement in the DM unambiguously increases H, as well as w and X.

$\gamma = 1$ is free.

In Appendix D we show that $F_e'' \geq 0$ implies V_e is a convex function $\hat{\gamma}$. This implies that any best response and therefore any Nash equilibrium must have $\gamma \in \{0, 1\}$. We already know $\gamma = 1$ is an equilibrium, so consider $\gamma = 0$. Let z_0 be the solution to $\ell(z_0) = i_n$ that gives us the equilibrium when $\gamma = 0$. Suppose e in the CM contemplates a one-shot (without loss of generality) deviation to $(\hat{\gamma}, \hat{m})$. Since V_e is convex in $\hat{\gamma}$, if such a deviation is to be profitable we may as well consider the best deviation, which is $(\hat{\gamma}, \hat{m}) = (1, 0)$ (it is clear that $\hat{\gamma} = 1$ implies $\hat{m} = 0$).

Let $V_e(\hat{\gamma}, \hat{m})$ denote the DM payoff when e chooses $(\hat{\gamma}, \hat{m})$, given others choose $\gamma = 0$, and given z_0. Then in the CM, after some algebra, e gains from the contemplated deviation iff $\Delta = z_0 + \delta V_e(1, 0) - \delta V_e(0, z_0) > 0$, since he saves on acquiring liquidity but also must weigh the consequences for DM trade. After more algebra,

$$\begin{aligned} \Delta \quad &\simeq \quad z_0 i_n + \alpha_e \theta \int_{z_0}^{\infty} \int_{R_i}^{\infty} (R_e - R_i) dF_e(R_e | R_i) dF_i(R_i) \\ &\quad - \alpha_e \int_{0}^{z_0} \int_{B_0(R_i)}^{\infty} [(1-\theta) R_e + \theta R_i - z_0] dF_e(R_e | R_i) dF_i(R_i) \end{aligned} \tag{16}$$

where $B_0(R_i) = \frac{z_0 - \theta R_i}{1 - \theta}$. Intuitively, a deviation to $(\hat{\gamma}, \hat{m}) = (1, 0)$ saves e the interest cost $z_0 i_n$ and allows trade at p' in region A_4 (the first integral), but also leads to trade a higher price in A_2 (the last integral).

If i_n is high, it is apparent that $\Delta > 0$ and the deviation is profitable. Consider $i_n \approx 0$, so that we can ignore this effect. Then Δ depends on θ. Clearly if θ is sufficiently low then $\Delta < 0$ and the deviation is *not* profitable;

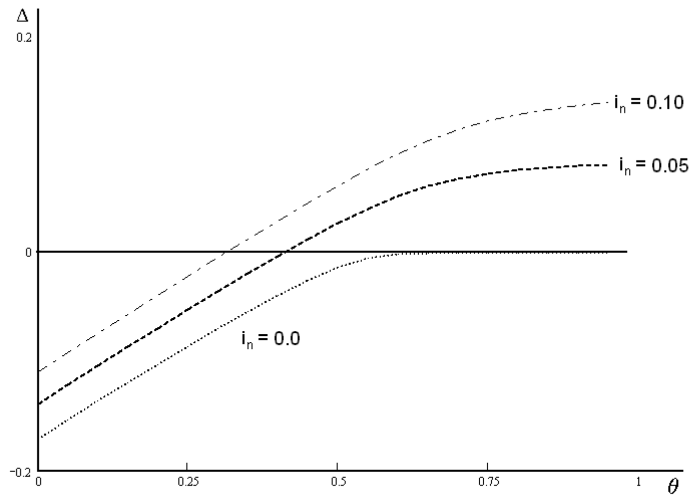


Figure 9: Deviation payoff for R_e and R_i independent lognormal.

intuitively, when $\theta \approx 0$ e gets very no surplus from trade at the CM price p' and so he may as well take a shot trading in the DM. Hence, when θ is low $\gamma = 0$ is an equilibrium. If θ is big, however, then $\Delta > 0$, and the deviation is profitable. See Figure 9. We summarize the results as follows.

Proposition 4 *There is always an equilibrium with $\gamma = 1$ and $z = 0$. There is an equilibrium with and $z > 0 = \gamma$ iff i_n and θ are not too big.*

7 Conclusion

We developed a framework to analyze the market for ideas when there are arguably realistic frictions, including matching, bargaining, and liquidity problems. We think the model generates interesting predictions about the trading outcomes in bilateral meetings, given liquidity z. It also yields strong predictions when liquidity is determined endogenously: equilibrium with $z > 0$ exists iff the interest rate i_n is not too big. It implies z is decreasing in i_n and, hence the amount of trade is maximized when $i_n \to 0$. Also, when $i_n \to 0$ equilibrium is socially efficient iff entrepreneurs have all the bargaining power ($\theta = 1$) due to a classic holdup problem. A result we find particularly interesting is that it is the best deals that are in the greatest danger of falling through.

In terms of more technical contributions, we showed how to introduce lotteries when the bargaining problem is nonconvex, which it may well be, due to a combination of indivisibilities and liquidity constraints. In terms of more substantive contributions, we showed some simple ways to model ideas as at least partially nonrival goods, and as intermediate inputs, which indicates how outcomes in the idea market can spill over in general equilibrium and affect wages, employment and other variables. We also showed that when agents get to endogenously choose γ, parameterizing the ease with which they can get around the liquidity problem, there can be equilibrium where they choose $\gamma = 0$.

The way we focus on liquidity in this market is not inconsistent with the papers discussed in the Introduction that conclude it is empirically relevant. But the precise way we model liquidity may generate some different implications from existing theories. For instance, if the problem in this market is simply borrowing constraints, high interest rates can help by increasing savings or at least making savings less painful; our approach suggests high interest rates make things worse by raising the cost of liquidity. This remains to be studied carefully, but it is clear at least that bargaining and liquidity interact in interesting ways. For example, with price taking, one can get over liquidity constraints by holding enough assets. Although of course this is costly, under bargaining there is a new cost that arises because the amount you pay can depend on your assets.

An obvious extension is to endogenize the number of innovators by a free entry condition and determine arrival rates endogenously (as Pissarides 2000 does for the labor market). Another is to make innovators pay ex ante to come up with ideas. Both of these extensions introduce two-sided holdup problems. Another generalization is to assume ideas have returns that are not i.i.d. across periods, introducing speculative considerations: e.g. innovators must decide whether to sell ideas to entrepreneurs with moderately high R_e, or hold out for even higher R_e. Another extension is to introduce richer financial institutions (Chiu and Meh 2006 have already made some progress on this). An explicit growth version of the model may also be worth pursuing. And, of course, adding private information seems worthwhile – to repeat what we said earlier, we abstract from private information here not because it is uninteresting, but to focus on other issues. All of this is left for future work.

Appendix A: Derivation of ℓ

Inserting the correct limits for the various regions, we can write (7) explicitly as

$$\begin{aligned} V_e(\hat{m}) &= \beta W_e'(\hat{m},0) + \alpha_e\beta\theta \int_0^{\phi'\hat{m}} \int_{R_i}^{B(R_i)} (R_e - R_i) dF_e(R_e|R_i) dF_i(R_i) \\ &+ \alpha_e\beta \int_0^{\phi'\hat{m}} \int_{B(R_i)}^{H(R_i)} (R_e - \phi'\hat{m}) dF_e(R_e|R_i) dF_i(R_i) \\ &+ \alpha_e\beta\gamma\theta \int_0^{\phi'\hat{m}} \int_{H(R_i)}^{\infty} (R_e - R_i) dF_e(R_e|R_i) dF_i(R_i) \\ &+ \alpha_e\beta\gamma\theta \int_{\phi'\hat{m}}^{\infty} \int_{R_i}^{\infty} (R_e - R_i) dF_e(R_e|R_i) dF_i(R_i). \end{aligned}$$

We now show how to differentiate this to get $\ell(\cdot)$ in the various cases.

(i) $\gamma > 0$ and $\theta < 1$. The derivative of the first term wrt $\hat{m}$ is $\beta\phi'$. By Leibniz Rule, the derivatives of the four integral terms are:

$$D_1 = \phi' \int_0^{\phi'\hat{m}} \frac{(\phi'\hat{m} - R_i)}{(1-\theta)^2} F_e'[B(R_i)|R_i] dF_i(R_i)$$

$$\begin{aligned} D_2 &= \phi' \int_0^{\phi'\hat{m}} \frac{(\phi'\hat{m} - R_i)(1-\gamma+\theta\gamma)}{\gamma^2(1-\theta)^2} F_e'[H(R_i)|R_i] dF_i(R_i) \\ &- \phi' \int_0^{\phi'\hat{m}} \frac{\theta(\phi'\hat{m} - R_i)}{(1-\theta)^2} F_e'[B(R_i)|R_i] dF_i(R_i) \\ &- \phi' \int_0^{\phi'\hat{m}} \int_{B(R_i)}^{H(R_i)} dF_e(R_e|R_i) dF_i(R_i) \end{aligned}$$

$$D_3 = \phi' F_i'(\phi'\hat{m}) \int_{\phi'\hat{m}}^{\infty} (R_e - \phi'\hat{m}) dF_e(R_e|\phi'\hat{m})$$
$$-\phi' \int_0^{\phi'\hat{m}} \frac{\phi'\hat{m} - R_i}{\gamma^2(1-\theta)^2} F_e'[H(R_i)|R_i] dF_i(R_i)$$

$$D_4 = -\phi' F_i'(\phi'\hat{m}) \int_{\phi'\hat{m}}^{\infty} (R_e - \phi'\hat{m}) dF_e(R_e|\phi'\hat{m})$$

Summing these and simplifying yields (9).

(ii) $\gamma = 0$ and $\theta < 1$. The results similar except for two things. First, $H(R_i) = \infty$ becomes vertical at $R_i = z$, so region A_3 vanishes and we can ignore D_3. Second, the derivative D_2 is not correct since we divided by $\gamma = 0$. The correct derivative in this case over region A_2 is

$$D_2 = \phi' F_i'(\phi'\hat{m}) \int_{B(R_i)}^{\infty} (R_e - \phi'\hat{m}) dF_e(R_e|\phi'\hat{m})$$
$$- \int_0^{\phi'\hat{m}} \frac{\theta(\phi'\hat{m} - R_i)}{(1-\theta)^2} F_e'[B(R_i)|R_i] dF_i(R_i)$$
$$-\phi' \frac{\theta(\phi'\hat{m} - R_i)}{(1-\theta)^2} \int_0^{\phi'\hat{m}} \int_{B(R_i)}^{\infty} dF_e(R_e|R_i) dF_i(R_i).$$

Summing now leads to (10).

(iii) $\theta = 1$. In this case $B(R_i) = H(R_i) = \infty$ both become vertical at z, and A_2 as well as A_3 vanish. Also, in this case the correct derivatives over regions A_1 and A_4 are

$$D_1 = \phi' F_i'(R_i) \int_0^{\infty} \left(R_e - \phi'\hat{m}\right) dF_e(R_e|\phi'\hat{m})$$

$$D_4 = -\phi' F_i'(R_i) \int_0^\infty \left(R_e - \phi'\hat{m}\right) dF_e(R_e|\phi'\hat{m})$$

Summing now leads to (11). ■

Appendix B: Existence

Here we derive some properties of $\ell(z)$ and use them to verify the results in Proposition 1, assuming to simplify the presentation differentiable densities, and $ER_j < \infty$. Also, we focus on the generic case $\gamma > 0$ and $\theta < 1$, and leave the rest as exercises. We claim first that $\lim_{z\to\infty} \ell(z) = 0$. Begin by rewriting (9) as $\ell(z) = \alpha_e \sum_{j=1}^4 I_j(z)$, where

$$\begin{aligned}
I_1(z) &\equiv \tfrac{1-\gamma}{\gamma^2(1-\theta)^2} \int_0^z z F_e' \left[H(R_i)|R_i\right] dF_i(R_i) \\
I_2(z) &\equiv -\tfrac{1-\gamma}{\gamma^2(1-\theta)^2} \int_0^z R_i F_e' \left[H(R_i)|R_i\right] dF_i(R_i) \\
I_3(z) &\equiv -\int_0^z F_e \left[H(R_i)|R_i\right] dF_i(R_i) \\
I_4(z) &\equiv \int_0^z F_e \left[B(R_i)|R_i\right] dF_i(R_i).
\end{aligned}$$

The claim is $I_j(z) \to 0$ as $z \to \infty$.

Consider $I_1(z)$, and suppose that $\int_0^\infty z F_e' \left[H(R_i)|R_i\right] dF_i(R_i) \nrightarrow 0$ as $z \to \infty$. Making a change of variable using $R_e = \frac{z - R_i(1-\gamma+\theta\gamma)}{\gamma(1-\theta)} = H(R_i) = H$, this is equivalent to

$$\int_0^\infty \left[\gamma(1-\theta)H + R_i(1-\gamma+\gamma\theta)\right] F_e'(H|R_i) dF_i(R_i) \nrightarrow 0 \text{ as } H \to \infty.$$

Integrating with respect to H over $(0,\infty)$, this implies

$$\begin{aligned}\infty &= \int_0^\infty\int_0^\infty \left[\gamma(1-\theta)H + R_i(1-\gamma+\gamma\theta)\right] F_e'(H|R_i)dF_i(R_i)dH \\ &= \gamma(1-\theta)\int_0^\infty\int_0^\infty HF_e'(H|R_i)dF_i(R_i)dH \\ &\quad +(1-\gamma+\gamma\theta)\int_0^\infty\int_0^\infty R_iF_e'(H|R_i)dF_i(R_i)dH,\end{aligned}$$

and hence either $ER_e=\infty$ or $ER_i=\infty$. Therefore, $I_1(z)\to 0$ as $z\to\infty$. Similar arguments show $I_j(z)\to 0$ as $z\to\infty$, $j=2,...4$, and we conclude $\ell(z)\to 0$ as $z\to\infty$.

Next we show $\ell(\underline{R})=0$, and $\ell(z)>0$ for some z in the neighborhood of $\underline{R}$, where $\underline{R}=\inf\{R|F_i'(R)F_e'(R|R)>0\}$ $\underline{R}<\infty$. First,

$$\begin{aligned}\ell(\underline{R}) &= \tfrac{1-\gamma}{\gamma^2(1-\theta)^2}\int_0^{\underline{R}}(\underline{R}-R_i)F_e'[H(R_i)|R_i]dF_i(R_i) \\ &\quad -\int_0^{\underline{R}}\left\{F_e[H(R_i)|R_i]-F_e[B(R_i)|R_i]\right\}dF_i(R_i) \\ &= \tfrac{1-\gamma}{\gamma^2(1-\theta)^2}(\underline{R}-\underline{R})F_e'[H(\underline{R})|\underline{R}]F_i'(\underline{R}) \\ &\quad -\left\{F_e[H(\underline{R})|\underline{R}]-F_e[B(\underline{R})|\underline{R}]\right\}F_i'(\underline{R})=0.\end{aligned}$$

Now consider

$$\begin{aligned}\ell'(\underline{R}) &= \tfrac{1-\gamma}{\gamma^2(1-\theta)^2}\int_0^{\underline{R}}\left\{F_e'[H(R_i)|R_i]+\tfrac{\underline{R}-R_i}{\gamma(1-\theta)}F_e''[H(R_i)|R_i]\right\}dF_i(R_i) \\ &\quad -\tfrac{1}{\gamma(1-\theta)}\int_0^{\underline{R}}\left\{F_e'[H(R_i)|R_i]-\gamma F_e'[B(R_i)|R_i]\right\}dF_i(R_i).\end{aligned}$$

After simplification

$$\ell'(\underline{R}) = \tfrac{1-\gamma}{\gamma^2(1-\theta)^2} F_e'(\underline{R}|\underline{R}) F_i'(\underline{R}) \left[1 - \gamma(1-\theta)\right].$$

By definition of $\underline{R}$, $\ell'(\underline{R}+\varepsilon) > 0$ for some $\varepsilon > 0$. Hence, $\ell(z) > 0$ for some z near $\underline{R}$. The combination of the results in this Appendix, $\ell(z) > 0$ for z near $\underline{R}$ and $\lim_{z\to\infty} \ell(z) = 0$, tells us that for small i_n there always exist solutions to $\ell(z) = i_n$, and for big i_n there does not, which is what we need for Proposition 1.

Appendix C: Lotteries

First, we verify that agents need not use lotteries in the CM. Assume e pays some amount p' to i in exchange for getting I with probability μ'. The payoff to e is $\mu' W_e'(\hat{m}_e - p', R_e) + (1-\mu') W_e'(\hat{m}_e - p', 0)$ and the payoff to i is $\mu' W_i'(p', 0) + (1-\mu') W_i'(p', R_i)$, while the threat points are as before. Hence the bargaining problem is:

$$\max_{p',\mu'} \left(\mu' R_e - \phi' p'\right)^{\theta} \left(\phi' p' - \mu' R_i\right)^{1-\theta}$$

Maximizing wrt p', we get $\phi' p' = \mu' \left[\theta R_i + (1-\theta) R_e\right]$. Using this, we can reduce the derivative wrt μ' to $(1-\theta)(R_e - R_i)(\mu' R_e - \phi' p')$. As long as $R_e > R_i$ and $\mu' R_e > \phi' p'$, both of which are necessary for trade, this is strictly positive for all $\mu' > 0$. Hence, for a maximum $\mu' = 1$.

Returning to the DM, the next claim is that profitable deals are never directly put on hold when we use lotteries. The usual calculation indicates that i puts a deal on hold iff $R_e > H(R_i)$, but now we have $H(R_i) =$

$\frac{\phi' \hat{m} - R_i \mu(1-\gamma+\theta\gamma)}{\mu\gamma(1-\theta)}$. Substituting μ from the bargaining solution into H, it is easy to show $R_e > R_i$ implies $R_e < H(R_i)$, establishing the claim.

Next we verify $\partial\Omega/\partial R_j < 0$, $j = i, e$. Considering i (the other case is symmetric), straightforward algebra yields $\partial\Omega/\partial R_i \simeq -c_1 R_e^2 - c_2 R_i R_e - c_3 R_i^2$, where c_1, c_2 and c_3 are functions of (θ, γ). One can show c_1, c_2 and c_3 are positive, the only tricky case being c_1 which is a complicated polynomial in θ and γ. Consider minimizing c_1 over (θ, γ). One can check that $c_1 > 0$ on the boundary of $[0,1]^2$, and then that $c_1 > 0$ at every possible critical point in $[0,1]^2$. So $c_1 > 0$ for all $(\theta, \gamma) \in [0,1]^2$, which establishes the claim.

Next we verify $\mu < 1$ iff $R_e > B(R_i)$. This follows from inspection of Figure 7. Suppose we fix R_i and increase R_e starting at $R_e = R_i$. Then we switch from $\mu = 1$ to $\mu < 1$ at some point, say $\tilde{R}_e = \tilde{R}_e(R_i)$. Since this is the same point at which switch from $p = [\theta R_i + (1-\theta) R_e]/\phi' < \hat{m}$ to $[\theta R_i + (1-\theta) R_e]/\phi' > \hat{m}$, this point is $\tilde{R}_e(R_i) = \frac{\phi \hat{m} - \theta R_i}{1-\theta}$, which tells us that $\tilde{R}_e = B(R_i)$. This completes the argument.

Finally, we verify $\partial\mu/\partial\theta > 0$ and $\partial\mu/\partial\gamma < 0$. The first derivative is simple, the second less so. Calculation yields $\partial\mu/\partial\gamma \simeq \Upsilon$, where

$$\begin{aligned} \Upsilon \equiv & -(1-\gamma+2\gamma\theta)R_i^3 + (1-3\gamma+6\gamma\theta)R_e R_i^2 \\ & +(1+3\gamma-6\gamma\theta)R_e^2 R_i - (1-\gamma+2\gamma\theta)R_e^3. \end{aligned}$$

Notice $\gamma = 0$ implies $\Upsilon < 0$. Now consider trying to maximize Υ. Since $\partial\Upsilon/\partial\theta = 2\gamma(R_e - R_i)^3 > 0$, as long as $\gamma > 0$, which it need be if we have any hope of $\Upsilon > 0$, we must set $\theta = 1$. Then $\partial\Upsilon/\partial\gamma = (R_e - R_i)^3(2\theta - 1)$, which is also positive given $\theta = 1$, and we must also set $\gamma = 1$. Hence, the maximum occurs at $\gamma = \theta = 1$, where $\Upsilon = -2R_i(R_e - R_i)^2 < 0$. This completes the argument. ■

Appendix D: V_e Convex in γ

The first partial of V_e wrt γ is

$$\begin{aligned}
\frac{\partial V_e}{\partial \gamma} &= -\alpha_e \beta \int_0^z \tfrac{(R_i - z)^2(1-\gamma)}{\gamma^3(1-\theta)^2}\ F_e'\left[H(R_i)|R_i\right] dF_i(R_i) \\
&\quad + \alpha_e \beta \theta \int_0^z \int_{H(R_i)}^{\infty} (R_e - R_i) dF_e(R_e|R_i) dF_i(R_i) \\
&\quad + \alpha_e \beta \theta \int_z^{\infty} \int_{R_i}^{\infty} (R_e - R_i) dF_e(R_e|R_i) dF_i(R_i).
\end{aligned}$$

Hence the second derivative satisfies

$$\begin{aligned}
\frac{\partial^2 V_e}{\partial \gamma^2} &\simeq \frac{(1-\gamma)\left[\gamma(1-\gamma) + 3(1-\theta)^2\right]}{\gamma^3(1-\theta)^3} \int_0^z (R_i - z)^2 F_e'\left[H(R_i)|R_i\right] dF_i(R_i) \\
&\quad - \frac{(1-\gamma)}{3\gamma^5(1-\theta)} \int_0^z (R_i - z)^3\, F_e''(H(R_i)|R_i) dF_i(R_i) \\
&\quad + \frac{\theta}{\gamma^3(1-\theta)^2} \int_0^z (z - R_i)^2\, dF_i(R_i)
\end{aligned}$$

The first and third terms are unambiguously positive. As long as $F_e'' \geq 0$, the middle term is also positive. ■

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