

# Matching Problems with Expertise in Firms and Markets

William Fuchs and Luis Garicano  
UC Berkeley                      LSE

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## Abstract

When should expertise be shared in markets and when in firms? Knowledge exchanges in the market involve less information about the quality of the provider's expertise, but facilitate good utilization of experts knowledge. In a firm, management holds soft information about individuals expertise and thus improves on the matching of experts to problems; however, the usage of experts is not smooth and thus firms experience over or under-utilization of experts' time. Thus the trade-off between firms and markets is between utilization (the market allows for better, smoother, utilization of knowledge than firms) and the quality of matching between problems and problem solvers (the market provides less information about experts' quality).

# 1 Introduction

The miracle of economic organization is that each individual only has available to himself a tiny fraction of the knowledge that he requires to survive. Most of us would be unable to repair the cars we drive, or raise the tomatoes we eat, not to say drive the planes we fly on or program the computers on which we work. Often, trade does not require that any knowledge be exchanged; instead, what is exchanged are just the objects that embody such knowledge. It is sometimes important, however, that individuals collaborate, so that different pieces of knowledge combine in the production of some good. Such exchanges often take place within the firm: a worker asks a supervisor or a colleague for help in solving some particular problem. Other times, they take place in the market: the same worker may hire an outside consultant so that he can benefit from his knowledge in designing a good. On many occasions, both exchanges may involve knowledge of similar nature. What makes one or the other form of exchange preferred? The traditional answers within the organizational economics literature have to do with the need to provide incentives for specific investments in a context where hold up is possible (due to incomplete contracts) (Grossman and Hart, 1986). These arguments apply to exchanges of goods, but not necessarily to exchanges of expertise, where no physical verifiable exchange may actually take place. This paper investigates the advantages and disadvantages of firms vis-a-vis markets in structuring the exchange of knowledge.

We study a simple model of a continuum of heterogeneous agents (following the work of Garicano and Rossi-Hansberg, 2004 and 2006) who are involved in production. Production requires their time and knowledge. When a problem is easy for them (it requires less knowledge than they have) they solve it; otherwise, they can ask other workers for help in solving it. Differently from previous work, agents do not know each other's skill. First, the skill of those asking for help is unobservable, so that the problem they are dealing with could be easy or hard depending on whether the worker asking for help is smart or not. Second, the skill of those providing help is also unobservable, so that it may be the case that an agent misrepresents himself as an expert when in fact his knowledge is basic. Under these circumstances, an unregulated market simply fails to exist. We face a case of extreme adverse selection, where a bad agent can completely conceal his lack of knowledge, offer his "expert" services and by doing so ruin the market. The problem is hard to solve in the case of knowledge, since its output is generally unverifiable, it is often uncertain whether output was at all produced. Consider, for example, a consulting firm advising on whether to undertake a merger or not— what is the difference between good advice and advice that is just plain worthless? We study two alternative solutions to this problem: an 'open

network’ or market, involving certification of experts; and a ‘closed network’, which we identify with a firm, where agents observe repeatedly each other’s skills and where, as a consequence, skill is observable.

A regulated market may provide a solution to this extreme adverse selection problem. A regulator may intervene and set up a minimum quality standard that ensures that agents who participate in it have a minimum level of expertise. The problem with such a market is that, since skill is only partially observable, the matching between problems and solutions is relatively poor- we find good agents using their time advising on simple problems, and mediocre agents trying to help with very difficult ones.

Private firms are an alternative solution to this. In our view, a crucial role of firms is to accumulate observations about individuals skills. A law firm knows well which lawyers can take hard problems and which ones can not. More broadly, it knows which lawyers work well under pressure, which ones handle well tough cross-exams etc. Given this repository of knowledge, the firm largely solves the asymmetric information problem.

However, the firm suffers from a problem that the market can solve well: given the random arrival of clients, the utilization of agent’s time is less intense under this ‘closed’ referral system, and some agents find themselves wasting their time. Exchanges in the market enable much better utilization, as the sheer size of the market allows for the smoothing of demand variation.

Thus in our view, the trade-off in knowledge exchange between markets and firms is one between utilization and matching: exchanges in markets allow for better, smoother utilization; while exchanges in firms allow for the use of finer ‘meta-knowledge’, knowledge about what each agent knows and thus improve matching. We believe that this trade-off accounts well for some empirical regularities. For example, most large corporations use outside law firms when they undertake a merger. In our view, the reason for this choice is that number of mergers they undertake is too small to justify having internal experts- their utilization rate would be too low. Similarly, companies such as Coca Cola or Ford use outside firms to design their publicity campaigns, in spite of the importance of such advertising to their brand. Again, the reason is probably that the number of campaigns undertaken is too low to justify an internal team, and the market allows to increase the utilization rate of knowledge, at the cost, as we have argued, of having to rely on talent whose quality is less well known.

## 2 The Model and First best

There is a continuum of income maximizing agents who are indexed by their level of knowledge  $z_i \in [0, 1]$ . Without loss of generality, we choose the index  $z$  so that

$z_i$  is measured in percentiles of the knowledge distribution – the distribution of  $z$  is thus uniform. Agents must first decide if they become problem originators or problem solvers (advisors). We will let  $O$  denote the set of agents that become originators and by  $S$  the set of agents that become solvers. If an agent is an originator then at the beginning of the period he draws a problem, with an associated difficulty level  $q \in (0, 1)$ ;  $q$  i.i.d. across problems and distributed according to  $F(q)$ , with density  $f(q)$ . The difficulty of the problem is unobservable so all originators attempt to solve their own problems. If  $z_i > q$  then an agent can solve the problem by himself and he gets a payoff of 1. If he cannot solve the problem he infers that  $q > z_i$  and can then seek an advisor who can potentially solve the problem for a fee. Since some originators might not choose to seek advice with their unsolved problems we will denote by  $A \subset O$  the subset of originators that do seek advice and by  $I \subset O$  the subset that remains independent.

The other option is for the agent to decide to become an advisor. Advisors can advise up to  $1/h$  agents on their problems, where  $h < 1$  is the helping cost (it costs a fraction  $h$  of time to help one other agent) in a given period. Advisors don't generate any problems of their own, that is, they are specialized in solving problems. Like originators, advisors can solve problems that are not too hard for them i.e.  $z_i > q$ . We will assume for simplicity that if neither the original agent nor the hired consultant can solve the problem then the problem goes unsolved.<sup>1</sup>

In another paper (Fuchs and Garicano, 2009), we show that when the agents types are public information the first best allocation coincides with the competitive equilibrium and displays positive sorting in the matching between originators seeking advice and solvers. Hence, it can be characterized by a matching function  $m(z) : A \rightarrow S$  and 2 cutoff types  $z_1$  and  $z_2$  where  $z_1 \leq z_2$ . Types  $z \in [0, z_1] = A$  are originators who seek advice, types  $z \in (z_1, z_2) = I$  originate problems but do not seek advice and  $z \in [z_2, 1] = S$  are advisors. The matching function satisfies:  $m(0) = z_2$ ,  $m(z_1) = 1$  and  $m'(z) = h(1 - F(z))$ .

### 3 Two-Sided Asymmetric Information

We now turn to the case in which the agents types are their private information. This becomes a trading problem with two-sided adverse selection. Consultants might want to pretend they are smarter than they truly are and originators might want to pretend that they are dumber (their unresolved problems are simpler) than they really are. Specifically, we analyze the case where output is unverifiable

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<sup>1</sup>See Garicano (2000) and Garicano and Rossi-Hansberg (2006) for a setting (without asymmetric information) in which several layers of advice are available, with homogeneous and with heterogeneous agents respectively. In those papers  $z$  is a choice of agents, whereas here it is given.

and ownership of the problem is non transferable. This would be the case, for example, in a professional service context.

When output contingent contracts cannot be written and ownership cannot be transferred the only type of market that can be set up is one with uncontracted wages in exchange for expert services. Implying originators must remain as full residual claimants and experts can only be paid an uncontracted fee. Since their payoff is uncontracted all experts must receive the same payment. Under these circumstances, the market breaks down completely. No trade can take place, as the lowest skilled agents in the economy can pretend to be smarter and become a seller of consulting services. Any fixed fee that is high enough to entice a highly skilled agent to become a consultant will induce the least skilled agents to misrepresent their knowledge and offer their "services" for this fee. This is the case because the expected earnings of becoming an originator are increasing on the agent's type but the expected earnings of becoming an expert (or pretending to be one) are independent of type. Hence, if there is some type that prefers to become a consultant then all types below want to follow the same path. This leads to:

**Proposition 1** *When output contingent contracts cannot be written and ownership cannot be transferred there cannot be a competitive equilibrium with trade of expert services.*

Note that in contrast to the classic lemons problem like in Akerlof (1970) the main reason for the market to break-down is not coming from an unravelling from high types exiting but rather from the excessive entry of low types. To illustrate, consider the market for brain surgeons. The fact that top brain surgeons are not differentially compensated from good brain surgeons is second order. The first order problem arises from the average Joe putting a white robe and offering to crack your head open. Hence, to be able to get the market operating, we must find a way to prevent the low types from becoming false experts.

In the next two sections we analyze two potential remedies to these informational problems: in Section 4 we consider a public solution, where the state intervenes to certify the quality of experts; and in Section 5 a private one where firms invest in monitoring agents quality and incur a cost.

## 4 A regulated market referral system

The difficulty of sustaining an equilibrium when output is unverifiable and ownership cannot be transferred comes from the low types pretending to be experts. A social planner can address this problem by regulating entry into the expert services market. In fact, in many professions there exists some sort of certification

with the purpose of signalling to potential consumers that the professional they are hiring has a level of expertise above some threshold. This can be rationalized if the person hiring these services cannot observe his ability level directly.

For example, in its description of the bar exam, the American Bar Association says the purpose of the license is to establish competence, through a showing that "the applicant holds an acceptable educational credential from a law school that meets educational standards, and by achieving a passing score on the bar examination.(...) [The exam's] purpose is to protect the public."

With this in mind, consider a benevolent planner that has the ability to set an exam of difficulty level  $c$  which allows agents with types higher than  $c$  to become certified experts. The question we study next is what is the optimal level of certification  $c^*$ ?

For a given level of certification  $c$ , those above that level may choose to be consultants or independents, those below are originators who may or may not choose to seek advice for their unsolved problems. Note first that if an originator of type  $z$  is willing to pay a fee to seek advice then any other originator of type  $z' < z$  will also be willing to pay such a fee.<sup>2</sup> Thus there exists a  $z_1$  such that all agents  $z < z_1 \leq c$  seek advice. Second there may or may not exist an interval  $[z_1, c]$  of originators who do not seek advice. Third, without loss we can rule out the case in which there would be independents in an interval  $[c, z_i]$ , since the cutoff  $c$  could then be raised at no cost. Fourth, note that if an agent  $z > c$  prefers to be an independent rather than a consultant, then all agents  $z' > z$  would also choose to be independent.<sup>3</sup> In principle there can be a set of high types  $[\bar{z}, 1]$  that prefer to remain independent rather than participating in the market.

A competitive equilibrium with certification can be defined as:

**Definition 1 (CE with Certification)** *A Competitive Equilibrium with Certification consists of: A certification level  $c$ , a fee for consulting services  $w$  and cutoff  $z_1$  and  $\bar{z}$  such that:*

- i) Entry to the expert sector is optimal:  $F(\bar{z}) \leq \frac{w}{h}$  with equality if  $\bar{z} < 1$ .*
- ii) Seeking expert advice is optimal for all  $z \leq z_1$ :  $w \leq \Pr(q < m | q > z, m \sim U(c, \bar{z}))$  with equality at  $z = z_1$  if  $z_1 < c$*
- iii) Market Clears:  $\int_0^{z_1} (1 - F(z)) dz = \frac{\bar{z} - c}{h}$*
- iv) Feasibility:  $z_1 \leq c \leq \bar{z} \leq 1$*

The total output in the CE with Certification is:

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<sup>2</sup>Since the problems he seeks advice on are in expectation easier the lower the originator's type, the payoff of receiving advice are higher in expectation.

<sup>3</sup>This follows because while the income of an expert is not a function of his type, the income of an independent is increasing in his type.

$$Y = \int_0^{z_1} \left( (1 - F(z)) \Pr(q < m | q > z, m \sim U(c, \bar{z})) \right) dz + \int_{z_1}^c F(z) dz + \int_{\bar{z}}^1 F(z) dz$$

The planner can pick from different competitive equilibria by changing the certification level to maximize total output. Alternatively, subject to the proper constraints, we can think of the planner as choosing the size and level of expertise in the market as determined by the triple  $\{z_1, c, \bar{z}\}$ . Where  $[0, z_1]$  determines the size of the market for advice and  $[c, \bar{z}]$  determines the average quality.

Recall that in the first best it is always the case that the best agents participate in the consulting market i.e.  $\bar{z} = 1$ . However, with information constraints, the consulting fees are the same for all experts which particularly hurts the highest types. Hence, these agents might now prefer to abandon the market. By increasing the certification level the planner can increase the earnings of these agents to the point they again want to participate in the market. In a sense the planner faces a quantity versus quality trade-off because by increasing  $c$  he also excludes some agents from the consulting market. The distribution of problems determines the extent of this trade-off. If there are very few hard problems then there is little gain in bringing in the highest types and a lot lost by increasing  $c$ . Hence, in general it might be optimal to leave the smartest agents out of the market but, if  $F(q)$  is uniform it can be shown that this is never the case, and thus the problem can be written in a simplified way as:

$$\max_{c, z_1, \bar{z}} \int_0^{z_1} (z + (1 - z) \Pr(q < m | q > z, m \sim U(c, 1))) dz + \int_{z_1}^c z dz \quad (1)$$

where  $m$  denotes the knowledge of the randomly matched solver and:

$$\Pr(q < m | q > z, m \sim U(c, 1)) = \int_c^1 \frac{m - z}{(1 - z)(1 - c)} dm$$

hence:

$$\max_{c, z_1} z_1 \int_c^1 \frac{m}{(1 - c)} dm + \int_{z_1}^c z dz$$

For  $c, z_1, \bar{z} = 1$  to be a competitive equilibrium conditions (i) to (iv) must be met.

Occupational choices (*conditions (i) and (ii)*). First, since all consultants earn the same fees— the best consultant must prefer to accept fees  $w$  and work in consulting earning  $\frac{w}{h}$  rather than originate and solve his own problems with

probability 1 and earn 1, that is:  $1 \leq \frac{w}{h}$ . Second, the marginal originator  $z_1$  must indeed prefer to pay a consulting fee rather than drop a problem he cannot solve. The cost of hiring a consultant is the consulting fee  $w$ ; the benefit is the conditional probability that a consultant of average quality,  $\frac{c+1}{2}$  can solve the problem, given that  $z_1$  could not,  $w \leq \frac{\frac{c+1}{2} - z_1}{1 - z_1}$ . Feasibility also requires that  $z_1$  (what the best originator solves on his own) is less than what the worst problem solver solves,  $z_1 < c$ . Finally, we have a market clearing condition.

When  $h$  is low the optimal certification threshold coincides with the cutoff type we would observe in a market with no informational frictions. The market is so productive that: 1) there is no need to further restrict entry in order to increase the returns (guarantee the participation) of the high types and 2) all originators are willing to pay the prevailing equilibrium consulting fee. The only inefficiency hence arises because, instead of assortative, the matching is now random. As  $h$  increases, providing advice becomes less efficient, the fees for consulting increase and high originators loose interest in seeking expert help in the market. This leads to an equilibrium with independents. Entry is being restricted relative to first best because high originators prefer to deal with their own problems without participating in the market for advice. Finally, when  $h > 0.692$  experts can solve very few problems and hence unless fees are increased they have an incentive to leave the market. In order to have originators willing to pay higher fees, the average quality of the expert sector must be increased and this is done by further restricting entry. The next proposition characterizes the competitive equilibrium. given one threshold, supply and demand of questions asked determines the other one. Specifically, for a given certification level  $c^*$ , the measure of originators is given by the threshold  $z_1 = 1 - \frac{1}{h} (h^2 - 2h(1 - c^*))^{1/2}$ .

**Proposition 2 (Too Little Advice)** *For  $F(q)$  uniform  $(0, 1)$ , the Competitive Equilibrium with Certification and the optimal certification level  $c^*$  are characterized as follows:*

1. *For  $h < .41667$ , there are no independent originators  $z_1 = c^* = \frac{1+h-\sqrt{1+h^2}}{h}$ . There are a continuum of fees  $w \in [h, 1/2]$  compatible with the equilibrium.*
2. *For  $0.41667 < h < 0.692$  : there is an interior equilibrium with independents; the fees are pinned down by the indifference condition of originators who do not seek advice. No constraint binds, and the equilibrium level of certification is derived from the first order condition of (1).*
3. *For  $0.692 < h < 1$  the fees are such that (1) the marginal originator is indifferent between having the problem solved or not; and (2) the marginal consultant is indifferent between being a consultant or an independent. This*

implies the certification level that solves  $\frac{c+1}{2} \frac{1-z_1}{1-z_1} \frac{1}{h} = 1$ . The number of consultants in this equilibrium is distorted downwards.

These results are related to the literature that has studied occupational licensing as a way to regulate the entry into the expert professions. After Arrow (1963) first advanced the hypothesis that entry regulation was a way to protect consumers under asymmetric information on expert quality, Stigler (1971) countered that entry regulations were captured by insiders.<sup>4</sup> A lively academic literature has followed on both sides. Shapiro (1986) argues that licensing provides incentives for human capital accumulation by the expert under moral hazard. Leland (1979) discussed entry requirements in a market with asymmetric information about quality, and showed that if insiders were in charge, the standard would be set too high. Our contribution is to show that in fact under asymmetric information licensing requirements might be more restrictive than the first best, even absent pressures from insiders.

## 5 A private solution: restricting referral networks to improve skill observability

In our view, firms are (among other things) private matching devices. Senior managers in the firm have soft information on the worker's long history of dealing with individual problems. They can use this information to improve the matching between talent and unsolved problems. Although beneficial in terms of observability, internal referral networks increase the variance in the utilization of workers time. While in the market an expert can find the right number of problems to work on, when constrained to a fixed network he will frequently find himself over or under worked.

We model this by assuming that knowledge hierarchies within firms are set up so that on average there is the right amount of problems per solver.<sup>5</sup> That is, there are  $n = \frac{1}{h(1-F(z))}$  originators per expert. The variance faced by the expert where problem originators are of skill  $z$  is then given by:

$$Var = nF(z)(1 - F(z)) = \frac{F(z)}{h}.$$

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<sup>4</sup>Friedman and Kuznets (1946) first argued that licencing far from helping consumers resulted in higher prices and lower quantity and quality of service. Empirical support for this view of licencing as an inefficent regulation has been found in accounting (Young, 1988), dentistry (Kleiner and Kudrle, 2000) and optometry (Haas Wilson, 1986).

<sup>5</sup>This is assumed for simplicity, in general the cost of ovedemanding and underusing an expert's time can be very different and therefore  $n$  optimally set above or below average demand.

Incorporating the cost associated with this variance, which for simplicity we will assume to be linear in the variance and parametrized by  $K$ , we can show that the planner's problem in this economy is:<sup>6</sup>

$$\max_{z_1} \int_0^{z_1} \left( F(m(z; z_1)) - \frac{K}{h} F(z) \right) dz + \int_{z_1}^{Z(z_1)} F(z) dz$$

Where  $m(z; z_1)$  denotes the matching that will take place as a function of the choice of  $z_1$  (the highest type of originator that would belong to a firm) and  $Z(z_1)$  (with  $Z(z_1) \geq z_1$ ) denotes the lowest type that is to become a solver within a firm.<sup>7</sup>

Taking the derivative with respect to  $z_1$  and grouping the terms to facilitate the interpretation, the *FOC* can be written as:

$$\begin{aligned} & - \left( \underbrace{\int_0^{z_1} f(m(z; z_1)) \frac{\partial m(z; z_1)}{\partial z_1} dz}_{\text{loss from worse matches}} + \underbrace{F(Z(z_1)) \frac{\partial Z(z_1)}{\partial z_1}}_{\text{loss from less originators}} + \frac{K}{h} F(z_1) \right) (2) \\ & = \underbrace{F(m(z_1; z_1)) - F(z_1)}_{\text{Extra output}} \end{aligned}$$

This condition is the same as the one we would obtain in the first best problem except for the extra term  $\frac{K}{h} F(z_1)$ . It is clear that the marginal value of ‘team output’ is now lower than in the first best, which means that  $z_1$  will be smaller than in the first best.

**Proposition 3** *A restricted referral (‘firm’) solution where workers may only refer problems to one individual problem solver is characterized by assortative matching, like in the first best but less teams are built,  $z_1^{firm} < z_1^{fb}$ .*

The restricted referral (‘firm’) solution improves on the assignment of problems to solution vis-a-vis a public, regulated expertise exchange market, at the cost of increasing the variance in utilization of experts time. The restricted ‘firm’ solution wastes some of the time of experts, while the market one misallocates some of their skill.

<sup>6</sup>The competitive equilibrium allocation will not differ from the planner's solution. The planner's problem is just simpler to characterize.

<sup>7</sup>Since optimal matching is assortative, the only thing that remains to pin down the matching function is the cutoff type  $z_1$  which determines the total demand for expert services.

## 6 Conclusions and Discussion

The lack of observability and verifiability of the knowledge of experts creates massive informational asymmetries. We show that these asymmetries go further than in a traditional (Akerlof) adverse selection case, as the market always is destroyed, since anyone can claim to be an expert. We study two alternative solutions. First, a public examiner could certify individuals (e.g. the Certified Public Accountant exam for accountants, or the Bar exam or solicitors exam for lawyers). These solutions allow for trade in the market, with two costs: the matching is not ideal, as these certifications only allow for broad, gross distinctions between individuals quality; moreover, too little trade takes place, as the exams have to be (optimally, not for monopolization reasons) quite restrictive. A second possibility is that individuals try to accumulate information about each other's quality through repeated observation. They form small teams, and they work together. This improves the matching, as we show; however, it introduces variance in the allocation, as individuals may or may need the help of the expert with whom they are paired.

The choice between market credentialling systems and referral networks depends on the comparison between the cost of wasting the time of experts versus wasting some of their skill through random matching. To the extent that heterogeneity between experts matters, firms should be preferred; to the extent that their time is very valuable and idleness is very costly, a credentialling market will be best.

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