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Middlemen and private information

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Abstract

In this paper, private information concerning the quality of consumption goods is introduced to motivate the role of intermediation. Agents endogenously choose whether to become middlemen by investing in a technology of verifying quality. It is shown that there exists an equilibrium where middlemen always trade high-quality goods when the private information problem is not severe and the investment cost of quality-testing technology is not too high. When the private information problem is relatively severe, middlemen sometimes trade for low-quality goods. The trade-off to having agents engage in intermediation as opposed to production is considered to determine middlemen's welfare-improving role. It is found that when exchange is significantly delayed in the sense that people do not execute trades because they cannot recognize the true quality of goods, expert middlemen can improve welfare.

JEL classification: E00; D82

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1. Introduction

It is widely recognized that there are many markets where intermediaries, such as brokers, retailers or middlemen, play an important role in facilitating trade. It is also recognized that, in order to study intermediation, we need a model in which intermediaries emerge endogenously, and we need to be

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precise about the trading frictions which lead to their existence and determine their performance. One example of such a model has been studied by Townsend (1978), who assumes that there is a transaction cost to each bilateral exchange, and then observes that intermediaries emerge because they can economize on these transaction costs. Another example is the model of Rubinstein and Wolinsky (1987), who introduce intermediation into a bilateral random matching model, and conclude that for intermediaries to be viable they must be more efficient in making contacts with buyers and sellers than buyers and sellers are in making contacts directly with each other.[1]

This paper takes a different approach by focusing on the frictions related to private information. That is, we introduce qualitative uncertainty concerning consumption goods, in the sense of Akerlof (1970), into a random matching model of the exchange process to study how middlemen emerge endogenously to mitigate the trading frictions caused by qualitative uncertainty. In particular, the model adopted here is closely related to the private information model that Williamson and Wright (1994) use to study the role of money.[2] Private information concerning the quality of goods may be the driving force behind intermediation in several markets in the real world. For example, there are middlemen in the markets of used cars, precious stones, antiques and art, who usually have more expertise in discerning the quality of goods than a typical buyer.

In the model presented here, agents endogenously choose whether to become middlemen by investing in a technology that allows them to identify quality. Middlemen buy and sell goods but they do not produce. This captures the idea that dealers are trade agencies only; although they can facilitate trades, they themselves do not produce goods. From an efficiency viewpoint, there is a trade-off to having agents engage in intermediation as opposed to production, and we can discuss whether the equilibrium will involve too much or too little intermediation. Moreover, middlemen are not obliged to buy or sell only high-quality output; this is also determined endogenously. Hence, we can discuss the factors that affect middlemen's trading strategies, as well as the interaction between intermediation and producers' strategies to bring high- or low-quality goods to the market.

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[1] A related paper by Bhattacharya and Hagerty (1986) uses a search model to show how intermediation can mitigate search externalities of the type studied by Diamond (1982), but they simply assume that all trades must go through intermediaries. Yavas (1994) studies a related model with endogenous search intensity. Winkler (1989) models frictions by restricting feasible trading relationships between agents.

[2] In addition to Williamson and Wright (1994), related models of private information and money include Trejos (1993), Cuadras-Morato (1994), Li (1995a) and Kim (1996). There are also studies of financial intermediaries in economies with private information, including Diamond and Dybvig (1983), Diamond (1984), Smith (1984), Williamson (1986), Boyd and Prescott (1986), and Krasa and Villamil (1992). These are not directly related to the current paper, where the focus is on middlemen as a way around the problem of qualitative uncertainty associated with bilateral trade.

To be more specific, we consider a barter economy in which producers choose to produce high- or low-quality goods, with low-quality goods being cheaper to produce but less desirable for consumption. Agents meet randomly in pairs over time, they carry unit inventories, and they trade when it is mutually agreeable. In a particular meeting, an agent may or may not recognize the quality of goods offered in trade. Hence, producers may have an incentive to take advantage of the lower cost to producing low-quality goods. People who accept a good of unknown quality then face the risk of accepting a lemon. This generates a potential role for middlemen who can use their special knowledge about quality to buy and sell goods in the market. Middlemen earn profits by selling goods for more than they pay. Buyers may be willing to pay this premium if they believe middlemen have a high enough probability of selling high-quality goods. Middlemen are not assumed to have an advantage in the search process, as in Rubinstein and Wolinsky (1987), but rather an advantage in terms of information.

We characterize equilibria in this economy in terms of two key parameters – the severity of the private information problem and the investment cost of middlemen's quality-testing technology, which represent the benefit and cost that people take into account concerning whether or not to enter the intermediation business. It is shown that when the private information problem is not too severe and middlemen's quality-testing technology is not too costly, there exists an equilibrium in which middlemen endogenously arise and they choose to always trade high-quality goods. This result implies that, without the centralized monitoring of middlemen, legal restrictions or reputation effects, the economy may still have the desirable outcome that expert middlemen are trustworthy. Middlemen choose to be honest in doing business simply because to trade low-quality goods and cheat customers is not profitable when there are enough informed agents playing a disciplinary role. However, if middlemen find it profitable to trade low-quality output and sell to uninformed customers, there is nothing that prevents them from so doing. This kind of equilibrium can also exist for some parameter values, especially when the private information problem is relatively severe.

In this economy, middlemen improve efficiency by increasing people's incentive to produce high-quality output as well as bringing high-quality goods from producers to customers, who might not realize those trading opportunities without middlemen. However, intermediation employs resources which could have been used in producing goods. Despite the qualitative uncertainty in this economy, allowing expert middlemen may or may not improve welfare, depending on whether the efficiency in facilitating trade can compensate for the loss in production. When the informational frictions do not cause much delay in exchange in the sense that it is in the agents' interest to always accept goods even if they are of unknown quality, the existence of middlemen removes resources away from production without generating comparable efficiency. Hence, welfare is reduced by having middlemen in the economy. If the informational frictions cause some problem that people do not execute trades because they cannot recognize the true quality of goods, expert middlemen can play a welfare-improving role. We even find a case that, when the private information problem is so severe that the only equilibrium would entail no trade if there was no middlemen technology, it is possible for a nondegenerate equilibrium to exist with active intermediation. Middlemen certainly improve welfare in this case, even though they sometimes trade low-quality goods.[3]

The rest of the paper is organized as follows. Section 2 describes the environment. Section 3 presents equilibrium conditions and discusses possible types of equilibria. Section 4 analyzes the existence of several qualitatively different types of nonintermediary and intermediary equilibria. Section 5 discusses welfare and related issues. Section 6 considers some extensions to the basic model. Section 7 concludes.

2. The basic model

Consider an economy populated by a continuum of infinitely-lived agents with total population normalized to one. Agents produce and consume goods at discrete points in continuous time. There is only one good which can be produced in high or low quality by all producers.[4] The cost in terms of disutility to producing one unit of high-quality goods is equal to $\gamma > 0$, and the cost of producing low-quality goods is 0. Consumption of q units of high-quality goods yields utility qu, if they are produced by other agents. Consumption of low-quality goods or one's own output yields no utility.[5] Commodities are freely disposable, divisible and storable at zero cost, but only one unit at a time. A good is not storable if it is divided.

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[3] A related study by Biglaiser (1993) also considers expert middlemen in an economy with qualitative uncertainty. In his model, middlemen are an exogenously imposed institution, the quality of goods is exogenously determined, and the focus is on constructing a bargaining model with asymmetric information and discussing the related issues. However, the goals in the current paper are to show how middlemen emerge endogenously to mitigate the frictions caused by private information, and how the existence of middlemen affects the exchange process, producers' incentive to produce high-quality output, and welfare.

[4] This is equivalent to (in terms of analysis) assuming there is a large number of differentiated goods, and consumption of any good, holding quality fixed, yields the same utility.

[5] The assumption that consuming one's own output yields zero utility is an easy way to generate a motive for trade, and is common in search-based models of exchange (see, for example, Diamond, 1982; Kiyotaki and Wright, 1991, 1993). For the details of relaxing this assumption in a generalized model, see Kiyotaki and Wright (1993).

In any bilateral meeting, an agent can recognize the quality of his trading partner's good with probability $\theta < 1$. The probability θ is independent across traders when they meet. However, an agent is allowed to invest in a quality-testing technology and become an expert middleman, who can always recognize the quality of goods. The identity of middlemen, and the fact that they always recognize the quality of goods, are public information. Agents do not know anything else about other agents' histories.

To become an expert middleman, an agent has to give up his production technology, pay cost δ (in terms of disutility) to get the quality-testing technology, and cost γ to be endowed with a unit of high-quality good as inventory. Similarly, to get back his production technology, a middleman needs to hold a unit of high-quality good as inventory and dispose of the quality-testing technology. In every period of time, expert middlemen have to pay cost δ to maintain their quality-testing technology.[6] Given that the entry decisions have been made, agents equipped with the production technology are called *producers* while agents equipped with the quality-testing technology are called *middlemen.*

Agents meet pairwise and at random according to a Poisson process with the arrival rate proportional to the number of other types of agents. Let β denote the arrival rate, which implies that the probability of meeting another agent is approximately equal to $\beta\Delta$ in a short interval of time Δ. We normalize $\beta = 1$ without loss of generality.

When two agents meet, they simply inspect each others' inventories and simultaneously announce whether or not to trade. A trade takes place when it is mutually agreeable. If both agree to trade, then they exchange their inventories. If at least one agent in the meeting refuses to trade, they simply leave the meeting and look for another trade partner. Sampling their inventories or sequential trade is not allowed in this economy.[7] After trade, the quality of each commodity is revealed if it was previously unknown.

Note that under the specified assumptions, in equilibrium whenever two producers trade, it is one-for-one swap of inventories. After consuming or disposing of the goods from trade, they can produce a new unit of commodity or choose to be a middleman.

When a producer and middleman meet, upon agreeing to trade, the middleman gives a portion $1 - q$ of his inventory to the producer, and the producer

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[6] We can interpret δ as the maintenance cost of machines which middlemen use to test the quality of goods, or the cost necessary to update the knowledge of verifying quality.

[7] This assumption prevents us from dealing with the problem of signaling the quality of goods, which, though interesting on its own, is not the focus of the current paper. Given this assumption, a fixed cost to producing one unit of high-quality goods and the specified storage technology, producers cannot provide marginal incentives to each other and also have nothing to bargain over.

gives one unit of output to the middleman. So, q can be viewed as the price charged by middlemen for the intermediation service. After trade, both agents leave the meeting and consume their shares of the good immediately. The producer then makes the entry and production decision, and the middleman chooses whether to stay in the intermediation business or go back to the production sector.

In general, the price q can be determined through bilateral bargaining between a middleman and producer. For simplicity, we assume that the middleman get to make a take-it-or-leave-it offer to the producer, which allows him to extract the entire trade surplus (see Section 6 for the discussion of more general bilateral bargaining). The determination of q depends on the types of equilibria and the types of agents involved in trade. We will be more specific about it when we describe and examine the existence of equilibria.

Note that in this economy, middlemen gain nothing by exchanging their inventories with each other. The reason is as follows. When a middleman trades with a producer, he consumes a portion q of his inventory while receiving one unit of output from the producer in return as new inventory. If middlemen trade with each other, they just swap their inventories without generating any consumption since neither can produce goods and they always have to keep one unit of inventory in hand as a middleman. Such an exchange does not make either one better off.

3. The equilibrium conditions

In this economy, agents have to make the following decisions. They have to decide to enter either the intermediation business or production sector. Based on that decision, at a point of time, a proportion of agents P_I are intermediaries, and the other $1 - P_I$ are producers. Hence, there may be direct trades and indirect trades in equilibrium. By direct trade, we mean a trade between two producers; by indirect trade, a trade between a middleman and producer. As we can see from the specified meeting technology, P_I determines how often an agent is involved in an indirect trade.

A producer has to decide which quality output to produce. Hence, at a point of time, there is a proportion of producers, P_{PH}, holding high-quality output, and the other, $1 - P_{PH}$, holding low-quality output. In addition, a producer has to choose trading strategies concerning whether to accept a good of high quality, low quality, or unrecognized quality. A middleman has to decide whether to trade for high- and low-quality goods and whether to stay in the intermediation business. So there is a proportion of intermediaries, P_{IH}, holding high-quality goods and the other, $1 - P_{IH}$, holding low-quality goods.

Note that in equilibrium when two producers meet and recognize each others' inventories as high quality they will always want to trade, but they will reject goods of low quality. A producer with low-quality output is willing to trade at every opportunity since at worst he gets another low-quality output back. Hence, the only nontrivial trading strategy for a producer is whether to accept or reject a commodity of unknown quality if he is currently holding high-quality output. When an arbitrary producer with high-quality output cannot recognize the quality of another producer's good in a meeting, let Σ denote the probability with which people believe that he will accept it, and let σ denote the best response. That is, if other producers are using Σ, a given producer chooses σ. In equilibrium, $\sigma = \Sigma$. Although a producer may also encounter an unrecognized good in a meeting with a middleman, the latter always makes an offer such that the former is (just) willing to accept.

When a middleman with high-quality inventory trades with a producer with high-quality output, he can consume a portion, Q_H, of his inventory, and get one unit of high-quality good from the producer as new inventory. Hence, he will always accept high-quality goods since the net trade surplus is strictly positive. The only nontrivial trading strategy for a middleman is whether or not to trade for low-quality goods. When a middleman holding high-quality inventory trades with a producer holding low-quality output, he gets to consume a portion, Q_L, of his inventory, and switches from holding high- to low-quality inventory. Note that middlemen with low-quality goods need to wait longer to make a trade since they can only cheat uninformed customers. When the current profit obtained from trading low-quality goods can compensate for the waiting cost, there is no technology or institution that can prevent them from so doing. Let Ω denote the probability that a random middleman accepts low-quality goods and ω the best response. That is, if other middlemen are using Ω, a given middleman chooses ω. In equilibrium, $\omega = \Omega$.

Agents choose entry, production, and trading strategies in order to maximize the expected discounted utility of consumption net of cost. In so doing, they take as given the strategies of others and probabilities of meeting other agents. We look for stationary Nash equilibria where the strategies and meeting probabilities are time-invariant and expectations are rational. We confine attention mainly to nondegenerate equilibria, where at least some high-quality goods are produced and consumed, and utility is strictly positive.

Let V_{Pj} and V_{Ij} denote the expected lifetime utility (or value function) for a producer and a middleman, respectively, holding a commodity of quality j, where $j = H$ and L denote high- and low-quality goods. Let $Z = \max\{-\gamma + V_{PH}, V_{PL}\}$ represent the expected value for a producer with nothing in inventory, who is deciding whether to produce high- or low-quality output.

In this paper we confine attention to the equilibria where people do not change their career decisions; i.e., middlemen (if there are any in equilibrium) choose to stay in the intermediation business and producers choose to stay in the production sector. For this to be incentive compatible, the payoffs in both sectors must satisfy the following conditions in equilibrium:

$$\begin{aligned} &V_{PH} > -\delta + V_{IH} \Rightarrow P_I = 0,\\ &V_{PH} < -\delta + V_{IH} \Rightarrow P_I = 1,\\ &P_I \in (0,1) \Rightarrow V_{PH} = -\delta + V_{IH}. \end{aligned} \quad (1)$$

For example, if there are middlemen in equilibrium, their pay-off must be higher than switching back to the production sector, i.e., $-\delta + V_{IH} \geq V_{PH}$. Similarly, for producers to stay in the production sector, the payoff must satisfy $-\gamma + V_{PH} \geq -\gamma - \delta + V_{IH}$. Hence, for it to be incentive compatible for both middlemen and producers to stay in their current careers we must have $V_{PH} = -\delta + V_{IH}$.[8] Note that given the assumptions on middlemen technology, middlemen with low-quality goods cannot switch back to the production sector, but we need to check the participation constraint, $V_{IL} \geq 0$, which guarantees that they do not want to drop out of the economy.

As for the production decision, let H denote the probability that producers choose to produce high-quality output and h an individual's best response. In equilibrium, $h = H$. The best response condition is described as follows: $V_{PH} - \gamma > (<) V_{PL}$ implies $h = 1$ ($h = 0$), and $h \in (0,1)$ implies $V_{PH} - \gamma = V_{PL}$. Note that what is relevant to others' strategies, such as whether to accept goods of unknown quality, is the probability of meeting an agent carrying high-quality goods, P_{PH}, not an individual's production choice H. Also note that there is a steady state condition connecting H and P_{PH}.[9] Hence, in this paper we characterize equilibria by P_{PH} rather than H. This reduces the algebra, but is logically equivalent.[10] Thus, the following conditions need to be satisfied in equilibrium:

$$\begin{aligned} &V_{PH} - \gamma > V_{PL} \Rightarrow P_{PH} = 1,\\ &V_{PH} - \gamma < V_{PL} \Rightarrow P_{PH} = 0,\\ &P_{PH} \in (0,1) \Rightarrow V_{PH} - \gamma = V_{PL}. \end{aligned} \quad (2)$$

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[8] This is pay-off-equivalent to the equilibrium where agents use mixed strategies in making career decisions.

[9] The steady-state condition is the following:

$$\begin{aligned} &(1 - P_{PH})[(1 - P_I)(1 - \theta)\Sigma + P_I\Omega]H\\ &= P_{PH}\{(1 - P_I)[\theta P_{PH}\alpha + (1 - \theta)\Sigma(P_{PH}\alpha + 1 - P_{PH})] + P_I\}(1 - H), \end{aligned}$$

where $\alpha = \theta + (1 - \theta)\Sigma$. The above equation just equates the inflow and outflow into the fraction of producers holding high-quality goods. Note that $H = 0 \Leftrightarrow P_{PH} = 0$; $H = 1 \Leftrightarrow P_{PH} = 1$; and $H \in (0,1) \Leftrightarrow P_{PH} \in (0,1)$ though it is not necessary $H = P_{PH}$.

[10] Alternatively, we can interpret the equilibrium with $P_{PH} \in (0,1)$ as a nonsymmetric pure strategy equilibrium where there is a subset P_{PH} of producers always producing high-quality goods, and a subset $1 - P_{PH}$ of producers always producing low-quality goods. Wright (1997) shows that there exists a nonsymmetric pure strategy equilibrium which is payoff-equivalent to the symmetric mixed strategy equilibrium.

Assume that all agents discount the future at the common rate $r > 0$. The expected value in flow return to a producer holding high-quality output is

$$rV_{PH} = (1 - P_I)[\theta P_{PH}\alpha(u + Z - V_{PH}) + (1-\theta)\max_{\sigma} \sigma A_P] + P_I\{\theta P_{IH}[(1 - Q_H)u + Z - V_{PH}] + (1-\theta)\max(A_I,0)\}, \quad (3)$$

where

$$\alpha = \theta + (1-\theta)\Sigma,$$

$$A_P = P_{PH}\alpha(u + Z - V_{PH}) + (1 - P_{PH})(Z - V_{PH}),$$

$$A_I = P_{IH}[(1 - Q_H)u + Z - V_{PH}] + (1 - P_{IH})(Z - V_{PH}).$$

A_P and A_I represent the expected values of accepting an unrecognized good from a producer and a middleman, respectively. Note that $A_I = 0$ because middlemen make take-it-or-leave-it offers to make uninformed customers indifferent between accepting and rejecting. Eq. (3) sets the flow return to a producer with high-quality output, rV_{PH}, equal to the sum of two terms. The first term is the probability that he meets a producer with a commodity which he identifies as high-quality, θP_{PH}, multiplied by the probability the other agent with a high-quality good is willing to trade, α, multiplied by the gain from trading, plus the probability that he meets a producer with something he cannot identify, $1 - \theta$, multiplied by the gain from choosing the acceptance probability σ. An agent is allowed to use a mixed strategy ($\sigma \in (0,1)$) here in case of being indifferent. The second term is the expected payoff from trading with a middleman.

The value functions V_{PL}, V_{IH} and V_{IL} satisfy similar Bellman's equations:

$$rV_{PL} = (1 - P_I)P_{PH}(1-\theta)\Sigma(u + Z - V_{PL}) + P_I P_{IH}\Omega(1 - Q_L)(u + Z - V_{PL}), \quad (4)$$

$$rV_{IH} = (1 - P_I)[P_{PH}Q_H u + (1 - P_{PH})\max_{\omega} \omega(Q_L u + V_{IL} - V_{IH})] - \delta, \quad (5)$$

$$rV_{IL} = (1 - P_I)P_{PH}(1-\theta)(V_{IH} - V_{IL}) - \delta. \quad (6)$$

Eq. (4) sets the flow return to a producer holding low-quality output, rV_{PL}, equal to the probability that he meets an uninformed producer with high-quality output who is willing to trade, $P_{PH}(1-\theta)\Sigma$, multiplied by the gain from trading, plus the probability he meets a middleman with high-quality inventory who is willing to trade, multiplied by the gain from trading. Eq. (5) sets the flow return to a middleman holding high-quality inventory equal to the gains from trading with a producer, minus the investment cost δ. The expected gains from meeting a producer is equal to the probability that he meets one with high-quality output, P_{PH}, multiplied by the gain from trading, $Q_H u$, plus the probability that he meets one with low-quality output, multiplied by the gain from choosing the acceptance probability ω. Middlemen are allowed to use a mixed strategy ($\omega \in (0,1)$) here in case of being indifferent. Eq. (6) sets the flow return to a middleman with low-quality inventory equal to the probability that he meets an uninformed producer with high-quality output, multiplied by the gain of switching from holding low- to high-quality inventory, minus the investment cost δ.

A *stationary equilibrium* where middlemen (if there are any) choose to stay in the intermediation business and producers choose to stay in the production sector is a vector of value functions $V = (V_{PH}, V_{PL}, V_{IH}, V_{IL})$, trading strategies $\tau = (\sigma, \omega)$, prices $Q = (Q_H, Q_L)$, and distribution of types and inventory holdings $P = (P_I, P_{PH}, P_{IH})$ such that (i) given prices Q, strategies τ, and steady state distribution P, the value functions V satisfy Eqs. (3)–(6); (ii) given V, Q, P and $\Omega, \sigma = \Sigma$ solves the maximization problem in Eq. (3), and given V, Q, P and Σ, $\omega = \Omega$ solves the maximization problem in Eq. (5); (iii) given V, prices Q are consistent with take-it-or-leave-it offers; (iv) given V,P and $\Omega \neq 0$, the participation constraint for middlemen with low-quality inventory holds ($V_{IL} \geq 0$); (v) given V, τ and P_{PH}, P_I satisfies (1); given V, τ and P_I, P_{PH} satisfies Eq. (2) and P_{IH} satisfies

$$P_{IH}(1 - P_I)(1 - P_{PH})\Omega = (1 - P_{IH})(1 - P_I)P_{PH}(1 - \theta). \tag{7}$$

Eq. (7) equates the inflow and outflow from the measure of middlemen holding low-quality goods.

Potentially, the strategic variables σ and ω and the steady state distribution P_I and P_{PH} can take values of 0, 1, or any number between 0 and 1. However, we can rule out some cases as follows. Since we are interested in nondegenerate equilibria, we consider only the cases with $P_{PH} > 0$. Note that $P_I = 1$ is not an equilibrium because if there is no production, intermediation generates no profit at all. One can also show that when $P_{PH} = 1$ (there is no lemons problem since only high-quality goods are produced), people have no incentive to be expert middlemen. When some low-quality output is produced ($P_{PH} \in (0,1)$), if there are no middlemen or middlemen do not trade for low-quality goods, $\Sigma = 0$ cannot be a nondegenerate equilibrium. If no one accepts unrecognized goods and low-quality goods, then low-quality goods are never produced; but then agents should accept unrecognized goods, which contradicts $\Sigma = 0$. Even if middlemen accept low-quality goods, $\Sigma = 0$ is not a nondegenerate equilibrium since the take-it-or-leave-it offers make the payoff to producer with low-quality output zero when $\Sigma = 0$. This implies that the payoff of producing high-quality output or being a middleman is also zero, which leads to a degenerate economy.

The potential nondegenerate equilibria, characterized in terms of (P_{PH},P_I, σ,ω), are shown in Fig. 1. Let ϕ denote any element in the open interval (0, 1). Thus, the notation $x = \phi, y = \phi$ means that $0 < x < 1$ and $0 < y < 1$, although

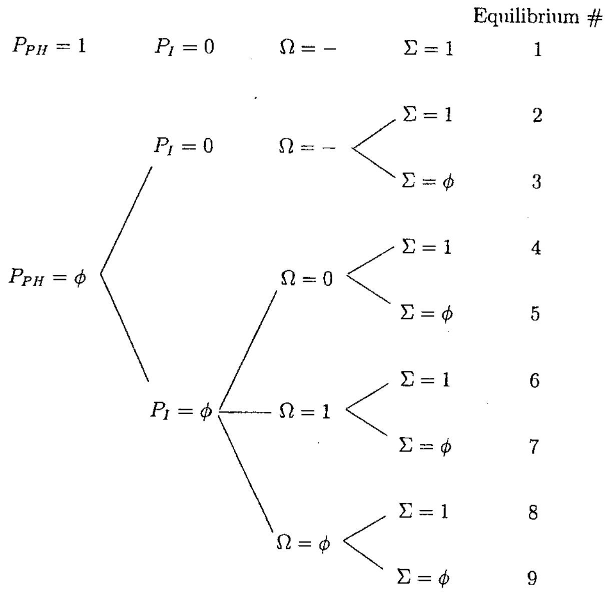

Fig. 1. Nondegenerate equilibria.

not necessarily $x = y$. For a particular equilibrium, 0, 1, and ϕ denote the values for $(P_{PH},P_I,\sigma,\omega)$, while dash '–' means that the strategy is irrelevant.[11] In the following sections, we will characterize and discuss the existence and welfare implications of those qualitatively different equilibria.

4. Existence of equilibria

In an economy with private information agents may not recognize the quality of goods at some meetings. Producers may try to take advantage of the lower cost to producing low-quality output and passing it off to uninformed agents. Therefore, there may potentially be some role for expert middlemen. Agent's decisions as whether to be a middleman and whether to trade lemons as a middleman depend on the cost of acquiring the quality-testing technology, and

[11] For example, if there are no middlemen, then their decisions as to whether or not to accept low-quality goods (Ω) is irrelevant. Fig. 1 also shows the logic of obtaining all the possible equilibria. For example, $P_{PH} = 1$ implies $P_I = 0$ and $\Sigma = 1$. When $P_{PH} = \phi$, there may or may not be middlemen ($P_I = 0$ or $P_I = \phi$), who may or may not take low-quality goods ($\Omega = 0$, 1 or ϕ). Given others' strategies, in a direct trade an agent may always accept unrecognized goods or may randomize ($\Sigma = 1$ or ϕ).

the profit of the intermediation business, which in turn depends on the severity of the private information problem.

There are nine potential nondegenerate equilibria, which we categorize into three groups: equilibrium without middlemen, equilibrium with middlemen who always trade high-quality goods, and equilibrium with middlemen who trade high- and low-quality goods. The algorithm to check the equilibrium conditions is as follows. For each type of equilibrium, we put the candidate strategic parameters and state variables into the value functions to solve for restrictions on parameters such that the equilibrium conditions are satisfied. We then use two key parameters, the cost of quality-testing technology (δ) and the extent of private information problem (θ) to characterize equilibria.

4.1. Equilibrium without middlemen

In this subsection we describe the existence of equilibria where agents do not find it profitable to be middlemen. There are three types of equilibria without middlemen (equilibria 1 to 3 in Fig. 1).

We start with the equilibrium with no lemons problem ($P_{PH} = 1$). If no low-quality output is produced, agents will always accept goods even when they cannot identify their quality; that is, $P_{PH} = 1$ implies $\Sigma = 1$. Next, we show that no one wants to invest in quality-testing technology and become a middleman when only high-quality output is produced.

Given $P_I = 0$ and $P_{PH} = 1$, the flow payoff to a producer holding high-quality output is the gain to producing and trading in every period of time: $u - \gamma$. Suppose that an agent is considering to deviate to be a middleman. The take-it-or-leave-it offer which he proposes to a trade partner (who always has high-quality output and knows that middlemen's inventories are of high quality in this equilibrium) is the price, Q_H, which makes the latter indifferent between accepting and rejecting. That is, Q_H solves

$$\max_{Q_H} \{Q_H u : (1 - Q_H)u - \gamma + V_{PH} \geq V_{PH}\},$$

which yields $Q_H = Q_1$ where[12]

$$Q_1 = (u - \gamma)/u. \tag{8}$$

Given the price $Q_H = Q_1$, the payoff to deviating as a middleman in a time interval and going back to the production sector is $u - \gamma + V_{PH} - V_{IH}$. This implies $V_{PH} = V_{IH}$. The expected values of a producer and a middleman with

[12] If the producer rejects the offer, his continuation value is simply V_{PH}. If he accepts the offer, he consumes $1 - Q_H$ unit of the middleman's good and then produces one unit of high-quality goods; the gain from trading is therefore $(1 - Q_H)u - \gamma + V_{PH}$. The middleman makes an offer to maximize his trade surplus so that the producer is just willing to accept.

high-quality goods are identical; however, middlemen have to pay cost δ. Hence, as long as it is costly to acquire the quality-testing technology, no one will deviate to be a middleman when there is no lemons problem.[13]

It now remains to check the condition under which producing high quality is a best response; i.e. producing high quality is unimprovable by a one-shot deviation. Substituting $P_{PH} = \Sigma = 1$ and $P_I = 0$ into Eqs. (3) and (4) one finds that $V_{PH} - \gamma \geq V_{PL}$ if and only if $\theta \geq \theta_1$, where

$$\theta_1 = (1 + r)\gamma/u. \tag{9}$$

So we conclude that equilibrium with $P_{PH} = \Sigma = 1$ exists when information is relatively abundant ($\theta \geq \theta_1$).

From now on, we will discuss the equilibria where producing low-quality output is as profitable as producing high-quality output ($V_{PH} - \gamma = V_{PL}$), which implies that it is the best response to produce high-quality output with any arbitrary probability. Since some low-quality output is produced, it may potentially be profitable to be a middleman, depending on the extent of qualitative uncertainty and the cost of being an intermediary agent. We use the same algorithm to check the equilibrium conditions for equilibria 2 and 3 (see Appendix B), and summarize the results as follows.

Equilibrium without Middlemen ($P_I = 0$)

1. There exists a nonintermediary equilibrium with $P_{PH} = \Sigma = 1$ if and only if $\theta \geq \theta_1$;
2. there exists a nonintermediary equilibrium with $P_{PH} \in (0,1)$ and $\Sigma = 1$ if and only if $\theta_1 < \theta \leq \theta_2$ and $\delta \geq \delta_1$; and
3. there exists a nonintermediary equilibrium with $P_{PH} \in (0,1)$ and $\Sigma \in (0,1)$ if and only if $\theta_3 < \theta < \theta_2$ and $\delta \geq \delta_2$, where θ_1 is defined in Eq. (9) and

$$\theta_2 = (1 + r)u/(2u - \gamma), \tag{10}$$

$$\theta_3 = \frac{r(u - \gamma) + \sqrt{r^2(u - \gamma)^2 + 4r\gamma(u - \gamma)}}{2(u - \gamma)}, \tag{11}$$

$$\delta_1 = \frac{\gamma(1 - \theta)[\theta u - \gamma(1 + r)]}{\theta(1 + r)(u - \gamma)}, \tag{12}$$

$$\delta_2 = \frac{\gamma(u - \gamma)[\gamma(\theta + r\theta - r) + u(1 + r - \theta - \theta^2)]}{(1 + r)[\theta(u - \gamma)^2 + \gamma u]}. \tag{13}$$

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[13] With a similar argument one can show that, when all agents have full information about the quality of goods, there is no role for middlemen. This result differs from the Rubinstein–Wolinsky model of middlemen, where middlemen are assumed to have an advantage in searching for buyers. This effect is ruled out here to highlight the role of information.

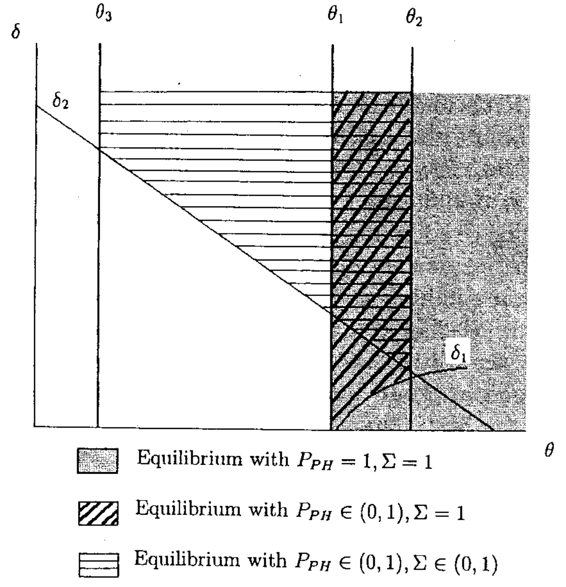

Fig. 2. Existence of equilibria without middlemen.

Note that there is a value of the discount rate, r^*, such that when $r < r^*$, we have $\theta_3 < \theta_1 < \theta_2$. In the following analysis, we consider only the cases where r is not too big ($r < r^*$). This implies that when the private information problem is severe enough ($\theta < \theta_3$), a nondegenerate equilibrium would not exist without middlemen technology.

For any given but arbitrary values of other parameters, we plot δ_1 and δ_2 as functions of θ, and values of θ_1, θ_2 and θ_3 in Fig. 2.[14] The results are clear from Fig. 2. First, when information is relatively abundant ($\theta \geq \theta_1$), there exists a 'first best' equilibrium ($P_{PH} = \Sigma = 1$). From society's viewpoint, this equilibrium is the best since the trading frictions cause no problems at all and there is no need to move resources away from production to intermediation. Second, given that $\theta_1 < \theta \leq \theta_2$ and the investment cost of being a middleman is big enough ($\delta \geq \delta_1$), there is an equilibrium in which some low-quality goods are produced, but still agents always accept unrecognized goods, and no middlemen appear. Third, when the private information problem is relatively severe ($\theta_3 < \theta < \theta_2$), and the investment cost is big enough ($\delta \geq \delta_2$), there exists an equilibrium where there are no middlemen and agents randomize accepting unrecognized goods.

[14] The parameter values used are $u = 2, \gamma = 1, r = 0.01$ in Figs. 2 and 3, and $u = 20, \gamma = 1, r = 0.01$ in Fig. 4.

4.2. Equilibrium with middlemen

In this subsection, we discuss the equilibria in which agents are willing to invest in information and become expert middlemen. We characterize analytically the equilibria where middlemen choose to do honest business (equilibria 4 and 5). However, under some circumstances, middlemen may find it profitable to trade lemons (equilibria 6 to 9). Since we are not able to get closed form solutions for this type of equilibria, we present the results by numerical examples.

Note that in this economy middlemen affect people's incentive to produce high-quality output through three different ways. First is the liquidity effect. Since middlemen always recognize and are willing to trade for high-quality goods, this makes high-quality output more liquid in the sense that it takes a shorter time to sell. Second is the inventory distribution effect. In the equilibria with trustworthy middlemen, the probability of getting high-quality goods is higher if people trade with middlemen rather than with producers. However, only producers holding high-quality goods can trade with middlemen in this type of equilibria. Third is the price effect. In the equilibria with dishonest middlemen, producers with high-quality output get higher expected gains than those with low-quality goods from trading with middlemen (for reasons that will be explained below); this also increases producers' incentive to produce high quality.

4.2.1. Middlemen trade high-quality goods only

When middlemen trade high-quality goods only, $\Omega = 0$, which implies that middlemen always have high-quality inventory ($P_{IH} = 1$). Hence, the price with which middlemen charge a producer holding high-quality output is Q_1, where Q_1 is defined in Eq. (8). We then determine the price with which a middleman would charge a producer with low-quality output if he had deviated toward trading lemons. The take-it-or-leave-it offer, Q_L, which makes a producer with low-quality output indifferent between accepting and rejecting solves

$$\max_{Q_L} \{Q_L u + V_{IL} - V_{IH}:(1 - Q_L)u + V_{PL} \geq V_{PL}\},$$

which yields $Q_L = 1$.

Note that in this type of equilibria, agents know that they have a higher probability in acquiring high-quality goods if they trade with middlemen rather than with other producers (since $P_{IH} = 1 > P_{PH}$). Therefore, an agent is willing to require less in return (by paying Q_1) for giving up his output when he trades with middlemen. In other words, agents pay more for middlemen's goods than for producers' goods because they believe that middlemen have a higher probability of selling high-quality goods.

Given $Q_H = Q_1$ and $Q_L = 1$, we use the same algorithm to check the restrictions on parameters such that there exists an equilibrium where middlemen always trade high-quality goods (see Appendix C). We summarize the results as follows.

Equilibrium with middlemen trading high-quality goods only

1. There exists an intermediary equilibrium with $\Sigma = 1$ and $\Omega = 0$ if and only if $\theta_4 < \theta \leq \theta_5$, $\delta < \delta_1$, $\delta \geq \delta_4$ and $\delta \leq \delta_3$ if $\delta_3 > 0$; and
2. there exists an intermediary equilibrium with $\Sigma \in (0,1)$ and $\Omega = 0$ if and only if $\theta_4 < \theta < \theta_5$, $\delta < \delta_2$, $\delta \geq \delta_5$ and $\delta < \delta_3$ if $\delta_3 > 0$, where

$$\theta_4 = \gamma/u, \tag{14}$$

$$\theta_5 = (u + \gamma)/2u, \tag{15}$$

$$\delta_3 = \frac{\gamma(1 - \theta)}{2\theta u - \theta\gamma - u}\delta_4, \tag{16}$$

$$\delta_4 = r(u - \gamma)/(1 + r), \tag{17}$$

$$\delta_5 = \frac{\theta\gamma^2 - \theta\gamma u(1 + \theta) + u^2(\theta^2 + \theta - 1)}{(\gamma - \theta u)(\theta\gamma + u - \theta u)}\delta_4. \tag{18}$$

Note that $\theta_4 < \theta_1 < \theta_2 < \theta_5$, and $\delta_1 = \delta_2 = \delta_3$ when $\theta = \theta_2$. The results are shown in Fig. 3. Some observations can be made. First, when information is abundant enough ($\theta > \theta_5$), intermediation is not feasible regardless of the value of δ. Second, given that the information problem is more severe but not too severe (say, $\theta_1 < \theta < \theta_2$), when the investment cost δ is big enough, the only equilibrium involves no middlemen. As δ decreases to a certain level, there arise equilibria with trustworthy middlemen. Third, when $\theta > \theta_1$, multiple equilibria coexist: the first best equilibrium and equilibria with trustworthy middlemen. Finally, given the extent of the private information problem, the intermediary equilibrium with $\Sigma \in (0,1)$ can exist at a higher investment cost when the equilibrium with $\Sigma = 1$ does not exist. The intuitive reason is as follows. If producers forgo direct trades sometimes when they cannot recognize quality of goods ($\Sigma \in (0,1)$), there is a higher profit for middlemen, so that they are willing to bear a higher investment cost to stay in the intermediation business.

4.2.2. *Middlemen trade high- and low-quality goods*

We have shown that when information is not too scarce and the investment cost δ is not too big, there exist equilibria where middlemen endogenously emerge and they choose to always trade high-quality goods. If information is relatively scarce, middlemen may not find it profitable enough to trade high-quality goods only, while agents may not have enough incentive to produce high quality. Hence, there cannot exist equilibria with trustworthy middlemen. However, if middlemen trade low-quality goods sometimes, the intermediation business may be profitable enough, and the existence of expert middlemen can increase agents' incentive to produce high quality. Thus, there may exist nondegenerate equilibria with dishonest middlemen when the private information problem is more severe.

When middlemen sometimes trade lemons ($P_{IH} < 1$), middlemen may have low-quality inventories which may or may not be recognized by other agents. This also affects the price with which middlemen can charge their customers. The take-it-or-leave-it offer which makes an uninformed producer with high-quality output indifferent is Q_2, where Q_2 solves

$$\max_{Q_2} \{Q_2 u{:}P_{IH}[(1-Q_2)u-\gamma+V_{PH}]+(1-P_{IH})(-\gamma+V_{PH})\geq V_{PH}\}.$$

Hence,

$$Q_2=\frac{P_{IH}u-\gamma}{P_{IH}u}. \tag{19}$$

As P_{IH} increases, Q_2 increases, which means that the price of intermediation service is higher when there are more middlemen holding high-quality goods.

In this type of equilibria, Q_2 is the *only* price that middlemen can charge to producers with high-quality output. Since $Q_1 > Q_2$ when $P_{IH} < 1$, an informed producer is willing to pretend that he is ignorant of the quality of goods in trade; i.e., he has no incentive to signal that he knows the quality. Note that Q_1 is not sustainable in this type of equilibria. Given price Q_1, uninformed producers will not trade with middlemen. Hence, middlemen with low-quality goods can never trade, which implies that accepting low-quality goods in the first place is not a best response, contracting $\Omega \neq 0$.

Note that even if middlemen may not guarantee a higher probability of offering high-quality goods in this type of equilibria, they can still increase people's incentive to produce high quality. Given $Q_H = Q_2$, producers with high-quality output get positive expected gains, as opposed to zero for those with low-quality output, from trading with middlemen.

Since we are not able to find closed form solutions for the equilibria with $P_{IH} < 1$, we discuss them by numerical examples (see Figs. 3 and 4). We can make the following observations. First, compared to the equilibria with trustworthy middlemen, equilibria where middlemen trade low-quality goods exist when the private information problem is more severe. This implies that, as the informed customers cannot play enough of a disciplinary role, middlemen will trade lemons and make a profit. Second, for some parameter values, equilibria with trustworthy middlemen and equilibria with dishonest middlemen coexist (see Fig. 4), while for other parameter values, there do not coexist multiple equilibria (see Fig. 3). Third, we find that when the private information problem is so severe ($\theta < \theta_3$) that the only equilibrium would entail no trade in the economy without middlemen technology, there can exist a nondegenerate equilibrium with dishonest middlemen. Allowing expert middlemen certainly

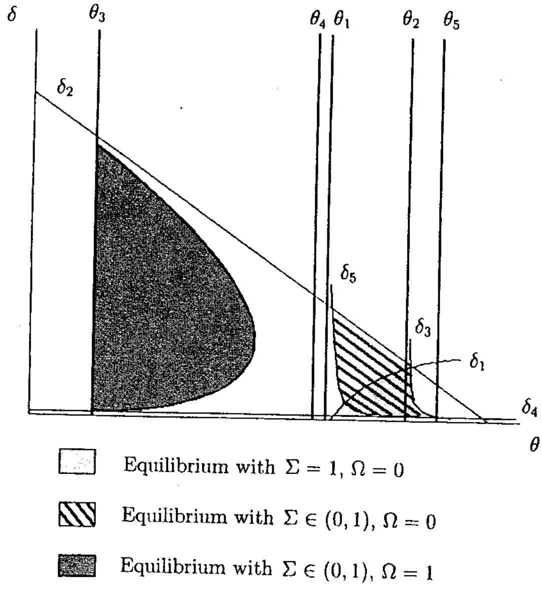

Fig. 3. Existence of equilibria with middlemen.

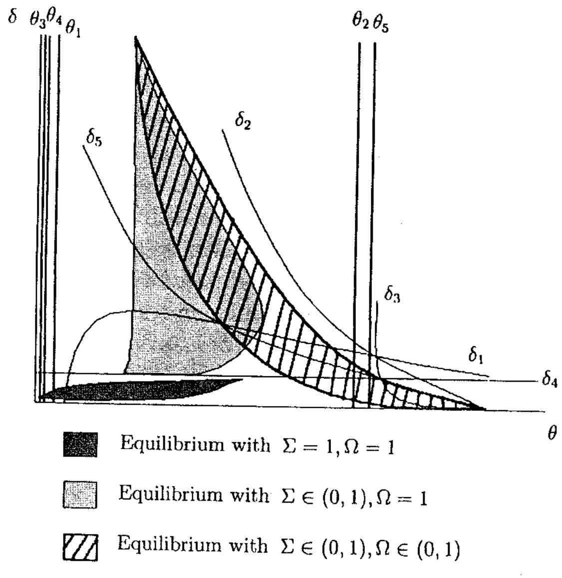

Fig. 4. Existence of equilibria with dishonest middlemen.

improves welfare in this case even though they sometimes trade low-quality goods and cheat uninformed customers.[15]

5. Welfare

In this section, we discuss welfare properties of the equilibria with trustworthy middlemen and do some welfare comparisons. Let W denote the welfare criterion, where

$$W = P_I V_{IH} + (1 - P_I)[P_{PH} V_{PH} + (1 - P_{PH}) V_{PL}]. \tag{20}$$

Welfare is determined by the frequency of trade and the probability of getting high-quality goods from those exchanges. For a producer, the frequency of trade depends on, among other things, P_I and Σ, which determine how frequent an agent is involved in direct trades and how many of those opportunities lead to exchanges. The endogenous variable P_{PH} determines the proportion of those exchanges giving the traders high-quality goods that generate utility. A middleman's expected utility is also determined by similar factors. Hence, we can rank equilibria according to those factors.

We have shown that when $\theta > \theta_1$, there coexist multiple equilibria – the first best equilibrium and equilibria with trustworthy middlemen (equilibria 1, 4 and 5). We compare welfare across those equilibria according to the criterion W defined in Eq. (20). Equilibrium 1 ($P_{PH} = \Sigma = 1$ and $P_I = 0$) has the highest frequency of trade and probability of consuming high-quality goods. Hence, it entails the highest welfare, which is the same as in the economy with complete information. We show by numerical examples that when there coexist equilibria with trustworthy middlemen, the one with $\Sigma = 1$ (equilibrium 4) Pareto dominates the one with $\Sigma \in (0,1)$ (equilibrium 5). From the numerical examples we know that equilibrium 4 has a smaller number of middlemen and a higher proportion of producers holding high-quality goods, which means agents are involved more frequently in direct trades which also lead to a higher chance of getting high-quality goods from trade. Hence, it generates higher welfare.

Another question is that, if the number of expert middlemen can be determined exogenously to maximize welfare, what would it be for different types of equilibria?[16] In Appendix D we show that when equilibrium 4 exists, the optimal number of middlemen is zero (given that the discount rate is not too

[15] Equilibrium with $\Omega = \Sigma = 1$ exists at a smaller δ (when $\delta < \delta_4$), and equilibrium with $\Omega \in (0,1)$ and $\Sigma = 1$ exists when δ is around δ_4. For further discussion, see Li (1995b).

[16] We need to take into account the incentive compatibility constraints for middlemen and producers – the condition for middlemen to stay in the intermediation business and the condition for producers being indifferent between producing high- and low-quality output. Also, the best response conditions for ω and σ have to be satisfied.

big). Hence, we conclude that the private intermediary equilibrium with $\Sigma = 1$ involves too many middlemen, in the sense that the number of middlemen always exceeds the optimal number. Note that in this equilibrium, it is in the agents' interest to always accept unrecognized goods in direct trades. Hence, the private information problem does not cause much delay in exchange. At the same time, if some agents become middlemen, resources are taken away from production. As the efficiency provided by middlemen to facilitate trades is less than the loss in production, welfare is decreased by introducing middlemen into the economy.

As for equilibrium 5, we discuss its welfare properties by numerical examples. Contrary to equilibrium 4, for some parameter values there is a strictly positive optimal number of middlemen in equilibrium 5. As the investment cost δ increases, the optimal number of middlemen decreases. There is a critical value of δ such that when the investment cost is higher than this critical value, the optimal number of middlemen is zero. We also find that as θ increases, the optimal number of middlemen decreases. This implies that if information is more abundant, there is less need for expert middlemen. There is also a critical value of θ above which the optimal number of middlemen is zero. Therefore, we conclude that allowing middlemen in this case can improve welfare if information is not too abundant and the investment cost of middlemen technology is not too big.

We find that in a large number of numerical examples the number of middlemen in equilibrium 5 is bigger than the optimal number; that is, there are too many middlemen. This brings out the issue of policy intervention in regulating intermediation, such as taxing middlemen by raising the investment cost δ. This policy can move some resources away from the intermediation business to the production sector and, therefore, enhance welfare. Note that the result of too many middlemen in this economy may be due to the local monopoly power of middlemen, in the sense that the price is determined by take-it-or-leave-it offers. In the next section, a more general bilateral bargaining is considered, and we have a somewhat different result regarding whether we get the right number of middlemen in this economy.[17]

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[17] Here we also report welfare comparisons for equilibria with trustworthy middlemen and those with dishonest middlemen. The welfare criterion is defined as follows

$$W = P_I[P_{IH}V_{IH} + (1 - P_{IH})V_{IL}] + (1 - P_I)[P_{PH}V_{PH} + (1 - P_{PH})V_{PL}].$$

Note that equilibria 4 and 5 (with trustworthy middlemen) and equilibria 7 and 9 (with dishonest middlemen) coexist for some parameter values (see Fig. 4). Numerical examples show that equilibrium 4 Pareto dominates equilibria 7 and 9, both of which Pareto dominate equilibrium 5. Hence, though some equilibria with honest middlemen entail higher welfare than those with dishonest middlemen, others do not. This implies that honest middlemen may not guarantee higher welfare. Note that the number of middlemen in equilibrium 5 is much bigger than those in equilibria 7 and 9 and, hence, the lower welfare is due to too many resources being employed in intermediation.

6. Some extensions

In this section, we present some extensions of the basic model. One is to consider more general bilateral bargaining between middlemen and their customers. Although for some retailers (such as supermarkets) there is no room for buyers to bargain over the prices, and so the take-it-or-leave-it offer is not an unsatisfactory assumption, one can observe bilateral bargaining between dealers and buyers in some markets. Another is to assume that the price for the intermediation service is determined by some trade surplus splitting rule (imposed on all transactions by some outside institution) rather than the bilateral bargaining. The focus is to study the effect of different trade surplus splitting rules on efficiency. Again, we consider only the stationary equilibrium in which middlemen are trustworthy.

The bilateral bargaining game considered here is the following one. When a producer with high-quality output meets a middleman, one of them is chosen at random to propose a price, q, which the other can accept or reject. If the offer is accepted, they trade and then leave the meeting to consume their shares of the good immediately. If it is rejected, they can choose whether or not to walk away from the bargaining table and search for new trading partners. If neither walks away, they wait a length of time Δ for another bargaining round, at which point someone is chosen at random to make a proposal, and so the process continues. It is assumed that agents never meet other potential trading partners during this time interval. In equilibrium, a middleman always proposes $q_m = q_m(\Delta)$, a producer always proposes $q_p = q_p(\Delta)$, and these proposals are always accepted.[18] As Δ becomes small, q_m and q_p converge to the same limit, which is the solution to an appropriately defined Nash bargaining problem.

Note that q_m and q_p are such that the proposer gets as much surplus as possible, subject to the other agent's acceptance of his offer. Therefore, they satisfy the following relationship

$$(1-q_m)u + Z = \frac{1}{1+r\Delta}\left[\frac{1}{2}(1-q_m)u + \frac{1}{2}(1-q_p)u + Z\right],$$

$$q_p u - \delta = \frac{1}{1+r\Delta}\left[\frac{1}{2}q_m u + \frac{1}{2}q_p u - \delta\right], \tag{21}$$

where Z is defined in Section 3. The left-hand side of the first equation is the value to the producer of accepting the offer q_m. The right-hand side is the

[18] In equilibrium, no one ever terminates the bargaining process voluntarily, and all offers are made so that they are accepted in the first round. Although offers are never rejected in equilibrium, it is the threat of rejecting and delaying settlement that drives the solution. See, for example, Osborne and Rubinstein (1990), Trejos and Wright (1995).

expected discounted value of rejecting: with equal probability each of the agents gets to make the next offer, and the offer of either case is accepted (in equilibrium). The second equation has a similar interpretation for a middleman evaluating the producer's proposal. Note that since we consider only the equilibrium where middlemen always trade high-quality goods, there is no private information problem in the bargaining game even when a producer cannot recognize the quality of the middlemen's goods. Thus, the producer knows the middlemen's reservation value so he can propose the offer, q_p, which satisfies Eq. (21).

One can show that as $\Delta \to 0, q_m = q_p = q$, and q is the solution to a properly defined Nash bargaining problem, from which one can solve for $q = q_h$, where

$$q_h = (u - \gamma)/2u.$$

The outcome of the bargaining game, q_h, splits equally the net trade surplus between a middleman and producer. Note that given $q = q_h$, participation of both agents is guaranteed.[19]

Since the model is complicated, we analyze some numerical examples and summarize the findings as follows. First, compared to the basic model, in the equilibria with bilateral bargaining there are fewer middlemen, and the proportion of producers with high-quality output can be higher or lower; however, the probability of acquiring high quality goods from trade is always higher and, hence, welfare is higher. Second, given other parameter values, equilibria with bilateral bargaining exist in a smaller region of (θ,δ) space. The trade surplus splitting rule is less favorable to middlemen so that it requires a lower investment cost for people to stay in the intermediation business. Third, even though q_h is bilaterally efficient, it may not be socially optimal. That is, q_h may not be the price that a social planner would choose to maximize welfare. Finally, given the bargaining outcome q_h, the number of middlemen that maximizes welfare may be bigger than that in a private equilibrium. This means that we may have too *few* middlemen in this economy. Hence, we can attribute the reason for the result of too many middlemen in the basic model to middlemen's local monopoly power implied by the assumption of take-it-or-leave-it offers.

The next step is to assume that the net trade surplus associated with a match of a middleman and producer is divided into the proportions p and $1 - p$, where p is the share for middlemen. The price Q_H can be expressed in terms of p as $Q_H = p(u - \gamma)/u$. We discuss the welfare properties associated with different trade surplus splitting rules p, without specifying how it is determined by an outside institution.

[19] One can also show that if a middleman had deviated to take lemons, the price determined by the bilateral bargaining is q_l, where $q_l = (u - \gamma + V_{IH} - V_{IL})/2u$. Hence, given $Q_L = q_l$, the best response condition for middlemen to not take lemons ($\Omega = 0$) is $u - \gamma + V_{IL} - V_{IH} \leq 0$.

Let $p^* = \arg\max W$ denote the surplus splitting rule that the social planner would dictate, if he could, to maximize welfare, taking into account that P_I, P_{PH} and all the value functions are functions of p^*. Suppose $p_m = \arg\max P_I V_{IH}$, which can be interpreted as the surplus splitting rule that maximizes the expected utility of a representative middleman. Thus, p_m is the price rule that middlemen would prefer, if they could impose it on all transactions.

From all the numerical examples we tried, $p_m > p^*$; that is, middlemen would prefer a price rule which may not be socially optimal. Moreover, $p_m > 1/2$, which means that middlemen would prefer a higher price than that determined by the bilateral bargaining game. Also, most cases show that $p_m < 1$; that is, middlemen may not prefer take-it-or-leave-it offers either. Those results may be due to the competition of the intermediation business in a private equilibrium. When the price is too much in favor of middlemen, there will be too many agents in the intermediation business. This results in lower production in the economy and, therefore, the profit per middleman may be too low. Hence, middlemen would prefer a price rule which balances the size of the intermediation business and the profit obtained per transaction, so as to maximize their expected utility.

7. Conclusion

This paper has analyzed the role of middlemen in an economy with private information concerning the quality of consumption goods. The trading frictions of private information motivate the existence of middlemen, who have an informational advantage over other agents by investing in a costly quality-testing technology. The feasibility and properties of intermediation depend on the extent of the private information problem and the cost of middlemen's quality-verification technology. If the cost is too big, despite the lemons problem in the economy, intermediation is not feasible. When information is relatively scarce, given that the quality-testing technology is not too costly, middlemen emerge endogenously and they always trade high-quality goods. If the private information problem is more severe, middlemen sometimes trade low-quality goods. When the private information problem is so severe that there would be no nondegenerate equilibrium without middlemen technology, there can exist a nondegenerate equilibrium with active intermediation.

The welfare-improving role of middlemen depends on the efficiency and cost of intermediation to the economy. For the first best equilibrium and the equilibrium in which people always accept goods of unknown quality, the optimal number of middlemen is zero. Allowing expert middlemen cannot improve welfare even though there may be private information about the quality of goods in trade. For the equilibrium in which the exchange is significantly delayed in the sense that people may not execute trades because they cannot recognize the quality of goods, efficiency provided by middlemen in facilitating trades may compensate for the loss in production. Hence, middlemen can improve welfare in this type of equilibrium, especially when information is not too abundant and the investment cost of middlemen is not too big.

It is also shown that the allocation of resources in production and intermediation in equilibrium may not be optimal: there are too many middlemen. This raises the issue of policy intervention in obtaining efficient intermediation. In an extension of the basic model, we consider a more general bilateral bargaining model and suggest that the result of too many middlemen is not robust to relaxing the assumption of take-it-or-leave-it offers. Nevertheless, we find that when too many resources are employed in the intermediation business, government policy in regulating the intermediation activity (e.g. taxing middlemen by increasing the investment cost) can improve welfare.

This paper has taken a first step towards constructing a theory of middlemen or intermediaries based on qualitative uncertainty concerning consumption goods. The model, while somewhat complex, is tractable enough to provide several predictions concerning the behaviors of intermediaries. Future research may involve extending the model to address the interaction between middlemen and other institutions, such as fiat money, that can also be shown to mitigate similar problems of private information.

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Appendix A

Under the Poisson assumption and normalization $\beta = 1$, in a short time interval of length $\Delta > 0$, the expected value of being a producer with high-quality output is

$$V_{PH} = \frac{1}{1+r\Delta}\{\Delta(1-P_I)[\theta P_{PH}\alpha(u+Z) + (1-\theta)\max_{\sigma}(\sigma(A_P + V_{PH}) + (1-\sigma)V_{PH})] + \Delta P_I[\theta P_{IH}((1-Q_H)u + Z) + (1-\theta)\max(A_I + V_{PH}, V_{PH})] + [1 - \Delta(1-P_I)(\theta P_{PH}\alpha + 1 - \theta) - \Delta P_I(\theta P_{IH} + 1 - \theta)]V_{PH} + o(\Delta)\},$$

where $Z = \max(-\gamma + V_{PH}, V_{PL})$, and α, A_P, A_I are defined in Eq. (3). The probability of more than one arrival is proportional to $o(\Delta)$, where $o(\Delta)/\Delta \to 0$ as $\Delta \to 0$. Rearranging the terms, we have

$$r\Delta V_{PH} = \Delta(1-P_I)\left[\theta P_{PH}\alpha(u + Z - V_{PH}) + (1-\theta)\max_{\sigma} \sigma A_P\right] + \Delta P_I[\theta P_{IH}((1-Q_H)u + Z - V_{PH}) + (1-\theta)\max(A_I, 0)] + o(\Delta).$$

If we divide the last equation by Δ and take the limit as $\Delta \to 0$, it transforms into Eq. (3). Eqs. (4)–(6) can be derived similarly.

Appendix B

First, we check the equilibrium conditions for equilibrium 2. If $V_{PH} - \gamma = V_{PL}$, then it is a best response to produce high-quality output with an arbitrary probability. Substituting $P_I = 0$ and $\Sigma = 1$ into Eqs. (3) and (4), $V_{PH} - \gamma = V_{PL}$ can be solved for $P_{PH} = P_{H1}$, where

$$P_{H1} = \frac{\gamma(1-\theta+r)}{\theta(u-\gamma)}.$$

Note that $P_{H1} > 0$, and $P_{H1} < 1$ if and only if $\theta > \theta_1$, where θ_1 is defined in Eq. (9). Similarly, substituting $P_I = 0$ and $\Sigma = 1$ into Eq. (3) shows that $\sigma = 1$ is a best response if and only if $A_P \geq 0$ (i.e. $P_{H1}u - \gamma \geq 0$), which holds if and only if $\theta \leq \theta_2$, where θ_2 is defined in (10). We then check the condition under which no one wants to deviate to be a middleman. Given others' strategies and $Q_H = Q_1 = (u-\gamma)/u$, the payoff to deviating in a time interval is $rV_{IH} = P_{PH}(u-\gamma) + V_{PH} - V_{IH}$. Then, $V_{IH} - \delta \leq V_{PH}$ if and only if $\delta \geq \delta_1$ where δ_1 is defined in Eq. (12).

We next show the conditions for equilibrium 3. In this equilibrium, agents are indifferent between accepting and rejecting unrecognized goods in direct trades. The expected gain from accepting an unrecognized good being zero implies that $\sigma \in (0,1)$ is a best response. Hence, $A_P = 0$ can be solved for

$P_{PH} = P_{H2}$, where

$$P_{H2} = \frac{\gamma}{[(\gamma + (\theta + (1-\theta)\Sigma)(u-\gamma)]},$$

which is always between 0 and 1. Using $P_{PH} = P_{H2}$, we can solve for the value of Σ which yields $V_{PH} - \gamma = V_{PL}$:

$$\Sigma_1 = \frac{\theta(u-\gamma)(\theta - r) - r\gamma}{(1-\theta)[u - (u-\gamma)(\theta - r)]}.$$

One can show that $\Sigma_1 \in (0,1)$ if and only if $\theta_3 < \theta < \theta_2$ where θ_2 and θ_3 are defined in Eqs. (10) and (11), respectively. Given others' strategies, $P_{PH} = P_{H2}$ and $\Sigma = \Sigma_1$, people will not deviate to be middlemen if and only if $\delta \geq \delta_2$ where δ_2 is defined in Eq. (13).

Appendix C

First, we show the equilibrium conditions for equilibrium 4. Using $V_{PH} - \gamma = V_{PL}$ and $V_{IH} - \delta = V_{PH}$ one can solve for $P_{PH} = P_{H3}$ and $P_I = P_{I1}$, where

$$P_{H3} = \frac{\gamma[(1+r)\delta + r\gamma](1-\theta)}{r\gamma^2(1-\theta) + (1+r)\delta\theta(u-\gamma)},$$

$$P_{I1} = \frac{\gamma(1-\theta)[\theta u - \gamma(1+r)] - \delta\theta(1+r)(u-\gamma)}{\gamma(1-\theta)(\theta u - \gamma)}.$$

Note that $P_{H3} > 0$ and $P_{I1} < 1$. One can show that $P_{H3} < 1$ if and only if $\theta > \gamma/u$. Given $\theta > \gamma/u$, $P_{I1} > 0$ if and only if $\delta < \delta_1$ where δ_1 is defined in Eq. (12). Also, $\sigma = 1$ is a best response if and only if $P_{H3}u - \gamma \geq 0$, which holds when $\delta \leq \delta_3$ (if $\delta_3 > 0$) where δ_3 is defined in Eq. (16). If $\delta_3 < 0$, then $P_{H3}u - \gamma \geq 0$ always, so we can ignore this condition. Substituting P_{H3} and P_{I1} into $u + V_{IL} - V_{IH} \leq 0$, one can show that $\omega = 0$ is a best response if and only if $\delta \geq \delta_4$, where δ_4 is defined in Eq. (17). Note that when $\theta = \theta_5$, where θ_5 is defined in Eq. (15), $\delta_3 = \delta_4$. For this type of equilibrium to exist, it requires $\delta_3 \geq \delta_4$, so we impose the condition $\theta \leq \theta_5$.

We now show the equilibrium conditions for equilibrium 5. Again, $\sigma \in (0,1)$ implies $P_{PH} = P_{H2}$. From $V_{PH} - \gamma = V_{PL}$ and $V_{IH} - \delta = V_{PH}$ one can solve for $\Sigma = \Sigma_2$ and $P_I = P_{I2}$, where

$$\Sigma_2 = \frac{(u-\gamma)[\theta^2((1+r)\ \delta + r\gamma) - r\gamma]}{(1-\theta)[(1+r)\ \delta u - \theta(u-\gamma)((1+r)\ \delta - r\gamma)]},$$

$$P_{I2} = \{\gamma^3(-r+\theta+r\theta) + \gamma^2[-\theta^2 u + \theta(\delta + r\delta - 2u - ru) + 2ru + u] + \gamma[\theta^2 u^2 + \theta u^2 - (1+r)u(u - \delta + 2\theta u\delta)] + (1+r)\theta\delta u^2\} / \{\gamma(u-\gamma)(u(\theta^2+\theta-1) - \theta\gamma)\}.$$

One can show $P_{I2} > 0$ if and only if $\theta < \theta_6$ where

$$\theta_6 = [\gamma - u + \sqrt{\gamma^2 - 2\gamma u + 5u^2}]/2u,$$

and $\delta < \delta_2$, where δ_2 is defined in Eq. (13), and $P_{I2} < 1$ if and only if $\delta > \delta_6$, where

$$\delta_6 = \frac{r\gamma(u-\gamma)(u-\gamma-\theta\gamma)}{(1+r)[\theta(u-\gamma)^2 + \gamma u]}.$$

One can also show that $\Sigma_2 > 0$ if and only if $\delta > \delta_7$ and $\delta > \delta_8$, where $\delta_7 = r\gamma(1-\theta^2)/[(1+r)\theta^2]$ and $\delta_8 = r\theta\gamma(u-\gamma)/[(1+r)(u-\theta(u-\gamma))]$, and $\Sigma_2 < 1$ if and only if $\delta < \delta_3$ if $\delta_3 > 0$. When $\delta_3 < 0$, $\Sigma_2 < 1$ so we can ignore this condition.

We then need to check $\omega = 0$ is a best response, which requires $u + V_{IL} - V_{IH} \leq 0$. Given $P_I = P_{I2}$, $\Sigma = \Sigma_2$, $P_{PH} = P_{H2}$ and $Q_H = Q_1$, one can show that when $\theta_4 < \theta < \theta_6$, $\omega = 0$ is a best response if and only if $\delta \geq \delta_5$, where δ_5 is defined in (18). Note that if $\theta < \theta_4$, then $u + V_{IL} - V_{IH} \leq 0$ if and only if $\delta < \delta_5$ but $\delta_5 < 0$. We thus impose the condition $\theta > \theta_4$. Some of the above conditions on δ are redundant. Note that when $\theta_4 < \theta < \theta_6$, $\delta_5 > \delta_6$ and $\delta_5 > \delta_7 > \delta_8$. Also note that $\theta_5 < \theta_6$.

The next thing to show is the condition for $\delta_3 \geq \delta_5$, which holds if and only if $u/(2u-\gamma) \leq c\theta \leq \theta_5$. When $\theta < u/(2u-\gamma)$, $\delta_3 < 0$ and $\Sigma_2 < 1$ always holds. Note that when $\theta = \theta_5, \delta_3 = \delta_4 = \delta_5$. Both δ_3 and δ_5 are negatively sloped at $\theta = \theta_5$ but δ_3 is steeper than δ_5; hence, $\delta_3 \geq \delta_5$ when $\theta < \theta_5$. However, we cannot draw a general statement about the relative magnitudes of δ_2 and δ_5. We conclude that this type of equilibrium exists if and only if $\theta_4 < \theta < \theta_5$, $\delta < \delta_2$ and $\delta_5 \leq \delta \leq \delta_3$ (if $\delta_3 > 0$).

Appendix D

Here we show the optimal number of middlemen is zero in equilibrium. The incentive constraint in producing high quality ($V_{PH} - \gamma = V_{PL}$) implies $P_{PH} = P_{H3}$ where

$$P_{H3} = \frac{\gamma[(1-P_I)(1-\theta) + r]}{\theta(1-P_I)(u-\gamma)}.$$

Note that $P_{H3} > 0$ always and $P_{H3} < 1$ if and only if $\theta > \theta_\alpha$ where $\theta_\alpha = \gamma(1 - P_I + r)/u(1 - P_I)$. We then have to check that $\sigma = 1$ is a best response, which requires $\theta < \theta_\beta$ where $\theta_\beta = u(1 - P_I + r)/[(2u - \gamma)(1 - P_I)]$. Note that $\theta_\beta > \theta_\alpha$ always. Since we consider only $r < r^*$, we have $\theta_4 < \theta_\alpha < \theta_\beta < \theta_5$, where θ_4 and θ_5 are defined in Eqs. (14) and (15).

Let $W_1 = rW$, where W is defined in Eq. (20). We show that W_1 is always downward sloping in P_I given $\theta \in [\theta_4, \theta_5]$. Note that $\partial W_1/\partial P_I|_{P_I=0,\ \theta=\theta_4} = -\delta - (u - \gamma) - r\gamma < 0$, $\partial W_1/\partial P_I|_{P_I=0, \theta=\theta_5} = [-\delta(u + \gamma) + r\gamma(u - \gamma)]/(u + \gamma) < 0$ if r is not too big. That is, when $\theta_4 \le \theta \le \theta_5$, W_1 is downward sloping at $P_I = 0$. Note that $\partial^2 W_1/\partial P_I^2|_{\theta=\theta 4} = 0$ and $\partial^2 W_1/\partial P_I^2|_{\theta=\theta 5} = -\gamma(u - \gamma)/(u + \gamma) < 0$, which implies that the slope of W_1 remains negative for all P_I. Therefore, we conclude that when equilibrium exists, the optimal number of middlemen is zero.

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