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Intermediation in a Directed Search Model

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Abstract

We study the ability of competitive coordination service platforms (such as auction sites and real estate agents) to facilitate trade in a directed search model where buyers have unit demands and each seller only has one good to sell. The sellers' capacity constraint leads to a coordination problem as in a symmetric equilibrium without intermediation some sellers receive multiple buyers while some are left without any customers. We compare this equilibrium to one where sellers and buyers can choose to become intermediaries who coordinate the meetings. We find that roughly 20 percent of agents become intermediaries. As a result, a large part of the supply and demand in the economy vanishes. Moreover, the large amount of intermediaries actually reduces the meeting efficiency. Jointly, these effects imply that the gains from trade are roughly 25 percent lower than in the economy without intermediation.

Keywords: directed search, intermediation, middlemen

JEL Codes: D4, L1

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1 Introduction

Intermediation is a salient feature of the economy. Evident examples of intermediaries or middlemen include financial intermediaries and real estate agents. Stretching the interpretation a little, even grocery stores can be regarded as intermediaries. On the one hand, intermediaries facilitate trade by bringing interested parties together by overcoming coordination problems. On the other hand, intermediaries have long been disregarded as go-betweens who produce nothing, just wasting resources. We study the benefits and costs of intermediation, focusing on the intermediaries' pontential to alleviate the coordination problem between buyers and sellers in a set-up where intermediation costs arise endogenously.[1]

We consider a directed search model with buyers and sellers who meet to trade. The buyers have unit demands, and the sellers are capacity constrained each one possessing one unit of a good for sale. The sellers post prices in a competitive fashion to attract buyers. In a symmetric equilibrium every seller posts the same price, and the buyers contact each seller with the same probability, i.e., randomly. In such an equilibrium capacity constraints are behind the coordination problem. Some sellers are contacted by many buyers, while some other sellers are not contacted by any buyers.

In this setting we introduce intermediation by assuming that agents can choose to become intermediaries whose rationale is to coordinate the buyers and sellers in their meetings. Such coordination services do not come for free. The intermediaries are agents who could be buyers or sellers, and becoming an intermediary means that some supply and demand, or potential for gains from trade, in the economy goes away. For example, if there are 100 buyers and 100 sellers, the theoretical gains from trade are achieved when all buyers and sellers trade, or there are 100 trades. If 10 agents of both groups become intermediaries, the theoretical gains from trade drop to 90 trades.

Furthermore, as the intermediaries do nothing else but bring together the

[1]Besidies overcoming coordination problems, intermediaries can facilitate trade via other means such as information production (see, eg., Spulber, 1999, for a survey of intermediaries' various tasks). We ingore such benefits of intermediation. Intermediation can also involve other costs (eg., transaction costs) beyond those to what we consider.

buyers and sellers who have contacted them, the most efficient outcome is to have just one intermediary. There is, however, free entry into intermediation which drives down its profitability, and also hinders coordination. As a result, we find that competitive intermediation reduces welfare not only because it consumes resources but also because it reduces meeting efficiency.

To compare the economy with and without intermediation we must determine the equilibrium market structure, or which agents become intermediaries. In equilibrium the agents have to expect the same utility regardless of the role they choose; this equivalence pins down the size of the intermediation sector. The determination of the agents' expected utility with intermediation requires modelling the price setting game among intermediaries. As is well known (see, eg., Gehrig, 1993), modelling price competition among intermediaries is non-trivial since the intermediaries provide coordination services, and prices do not direct the agents' choices in the same way as in the economy with buyers and sellers only. Our short-cut in the modelling of price competition is the assumption that buyers and sellers are not fully rational in the sense that they ignore the price effects on the other side of the market. This assumption allows us to pin down a unique equilbrium where intermediaries charge a price that balances competition for buyers and sellers, and where the intermediaries, buyers, and sellers fare equally well.

In the seminal paper, Rubinstein and Wolinsky (1987) study intermediaries, or middlemen, in a unit-supply, unit demand random matching framework of buyers and sellers. Equilibrium with middlemen exists if they are at least as efficient in meeting other agents as buyers and sellers are meeting each other. If a middleman becomes the owner of the good instead of just mediating trade the buyers' and sellers' shares of the gains from trade go down.

There is a long literature on intermediation building on Rubinstein and Wolinsky (1987) (see, eg., Wright and Wong, 2014, for a survey). In this tradition, a close paper to ours is Nosal, Wong and Wright (2016) who extend Rubinstein's and Wolinsky's (1987) framework to study efficiency and allow agents to choose to be either producers or middlemen. Thus, intermediation entails similar opportunity costs as in our paper, since an increase in the number of intermediaries comes at the cost of having fewer producers. They find that there can be too much or too little intermediation depending on the parties' bargaining powers.

Gehrig (1993) and Spulber (1996) introduce price competion among intermediaries in search settings. In Gehrig (1993), prices are public, whereas in Spulber (1996), prices are observable only after costly search but intermediation is costly, involving exogenous transaction costs. Rust and Hall (2003) build on Gehrig (1993) and Spulber (1996) and consider competition between market maker-type and dealer-type intermediaries. Fingleton (1997a) studies a setting where trading can be done either through a middleman who provides speed or through direct trade where markets are organised as in double auction but where putting up the market takes time. Fingleton (1997b) studies intermediation when the traders have direct trade as an alternative to using a middleman.

A closely related paper is Watanabe (2010) who considers intermediaries in a directed search model like we. The advantage of an intermediary is that he can hold larger stocks of goods than other agents, and consequently serve more people. As the buyers are interested in both the price and the probability of acquiring a good large inventories allow higher prices than low inventories.

Gautier, Hu and Watanabe (2017) study a model with a monopoly intermediary. The intermediary has a choice of holding inventory and of offering a platform for buyers and sellers. The buyers and sellers have an option to trade in the decentralised market, too. In this setting an intermediary can survive in the equilibrium, and offer both the platform and inventories.

Intermediation can be regarded as a platform, or a coordination device as, eg., in Rochet and Tirole (2003) and Armstrong (2006). Their focus is on pricing. The platform is the more valuable to a particular type (eg., buyer) the more of the opposite type (eg., seller) uses it. In this setting optimal pricing may entail subsidising one side of the market. It is also assumed that demand does not react too strongly to low prices to avoid Bertrand-like outcomes or cornering the market by one intermediary. In our model the intermediaries also provide coordination services but their number is determined endogenously.

Common to all these models of intermediary price competition, and different from our approach, is that there is no trade-off between having intermediaries or not; intermediaries are assumed to exist at the outset, and their existence does not constrain the resources of the economy.

In the rest of the article we first cover the benchmark directed search model where the sellers post prices, and the buyers contact them using symmetric strategies. The frictions that arise in equilibrium are quantified, and they form the rationale for intermediation. To treat all parties the same way we develop the benchmark into a model of equilibrium market structure. There both buyers and sellers may be the party that proposes the terms of trade and makes the contact decision. Only after this we analyse the setting where the agents can choose to become intermediaries. The main object is to determine the number of trades, which is our efficiency measure, in each setting.

2 The Model without Intermediaries

2.1 Sellers' Market

There are S sellers and B buyers in the economy. Ex ante all the sellers are identical, may produce a unit of a good at zero cost for sale, and value it at zero. The buyers are also identical, have unit demands and value the good at unity. The sellers post prices at which they commit to sell their unit supply. The buyers observe the prices and based on this information choose which seller to contact.

This situation is well-understood in a large economy where there is an infinite number of buyers and sellers; there exists a unique (symmetric) equilibrium in which all the sellers post the same price (eg., Kultti, 1999). If the ratio of buyers to sellers, or the expected queue length in a symmetric equilibrium, is θ then a seller meets k buyers with probability $e^{-\theta}\theta^k/k!$. Price competition does not drive prices to zero since the sellers are capacity constrained and the buyers are interested both in price and the probability of attaining the good. The equilibrium price turns out to be $p = (1-e^{-\theta}-\theta e^{-\theta})/(1-e^{-\theta})$. This price is increasing in θ: The larger the ratio of buyers to sellers, the more intense the competition among buyers and the more likely that a seller can trade even if he charges a higher price.

We can make the setting simpler by assuming that there are equal numbers of buyers and sellers, say a unit mass. Then the probability that a seller meets no buyers is e^{-1}. Consequently, the number of trades consummated is given by $1 - e^{-1} \approx 0.632$.

Result 1. *When the buyers contact the sellers the gains from trade, or the number of trades, is approximately* 0.632.

2.2 Equilibrium Market Structure

Result 1 is based on the setting where buyers contact sellers. Such an outcome is, however, not an equilibrium market structure: There is no reason for why sellers should not contact buyers. In particular the sellers in this setting where they are prevented from contacting buyers do worse than the buyers. Taking this observation seriously let us postulate that agents have the choice between waiting for the opposite type to contact them and contacting the opposite type. Allowing such a choice results in an equilibrium market structure with two markets. In the sellers' market some sellers post prices and some buyers contact the sellers. In the buyers' market the rest of the buyers post prices at which they are willing to buy the good, and the rest of the sellers contact them.[2] In equilibrium the sellers in both markets have to do equally well. The same applies to the buyers, too.

Let there be x buyers and y sellers in the sellers' market and denote the queue lenght by $\theta = x/y$. Then there are $1 - x$ buyers and $1 - y$ sellers in the buyers' market, and denote the queue lenght by $\rho = (1 - y)/(1 - x)$. In the sellers' market the price (what the sellers get if they trade) is $p_s = (1 - e^{-\theta} - \theta e^{-\theta})/(1 - e^{-\theta})$, and in the buyers' market the price (what the

[2] Such co-existence of the buyers' and sellers' markets is not just a theoretical construction but in many markets contacts may happen to both directions. Promiment examples include labour, real estate, and dating markets.

buyers get if they trade) is $p_b = (1 - e^{-\rho} - \rho e^{-\rho})/(1 - e^{-\rho})$.

In the sellers' market the sellers trade with probability $1 - e^{-\theta}$, and their expected utility is $1 - e^{-\theta} - \theta e^{-\theta}$. The buyers trade with probability $(1 - e^{-\theta})/\theta$, getting utility $1 - p_s$. Consequently, their expected utility is $e^{-\theta}$.

Analogously, in the buyers' market the sellers' expected utility is given by $e^{-\rho}$, and the buyers' expected utility by $1 - e^{-\rho} - \rho e^{-\rho}$.

Since the sellers must fare equally well in both markets, the equilibrium condition for the sellers is given by

$$1 - e^{-\theta} - \theta e^{-\theta} = e^{-\rho}. \tag{1}$$

For the buyers, we have similarly

$$1 - e^{-\rho} - \rho e^{-\rho} = e^{-\theta}. \tag{2}$$

From the equilibrium conditions (1) and (2) we can infer that

$$\theta e^{-\theta} = \rho e^{-\rho}. \tag{3}$$

It has been shown (Halko, Kultti and Virrankoski, 2008) that $\theta = \rho$ is the only solution to equation (3) such that buyers and sellers are equally well off. Consequently, equations (1) and (2) imply that the ratio of buyers to sellers in the sellers' market, and the ratio of sellers to buyers in the buyers' market, is given by the solution to

$$1 - 2e^{-\theta} - \theta e^{-\theta} = 0. \tag{4}$$

Since the left-hand side of equation (4) is strictly increasing and takes the value of -1 when $\theta = 0$, the equation has a unique solution. This solution is (approximately) $\theta \approx 1.146$. Thus, in equilibrium $1.146 \approx \theta^* = x/y = \rho^* = (1 - y)/(1 - x)$ which determines the equilibrium values of x and y uniquely as $x^* = \theta^*/(1 + \theta^*)$ and $y^* = 1/(1 + \theta^*)$.

The equilibrium number of trades is then given by

$$2\left(1 - e^{-\theta^*}\right) y^*. \tag{5}$$

Substituting $1/(1+\theta^*)$ for y^* in equation (5) and evaluating the resulting equation numerically shows that the equilibrium number of trades is almost the same as in the case where we just postulate that the buyers contact the sellers.

Result 2. *With two markets the gains from trade, or the number of trades, is approximately* 0.636*, ie., it is practically the same as when the buyers contact the sellers.*

3 Equilibrium Intermediation

We introduce intermediaries as agents that bring buyers and sellers together; they offer platforms for meetings. If j buyers and k sellers contact a particular intermediary he facilitates $\min\{j,k\}$ trades, and takes his share of each of them. The intermediaries attract the buyers and sellers by posting prices for their services just like the sellers did in the bench mark model in section 2.

Modelling price competition between coordination services is known to raise difficulties. If there are, say, two intermediaries who announce prices p and q, $p < q$, for their services, it is expectations that determine the agents' decision of which intermediary to contact. If everyone believes that everyone else will contact the high-price intermediary, then it is in everyone's interest to do so. Prices do not necessarily achieve coordination in this setting.

We therefore simplify the price setting game between intermediaries while allowing for strategic behaviour. We assume that mass z of both buyers and sellers become intermediaries. They attract the remaining buyers and sellers by announcing prices that they take of each successful trade. Price competition is restricted by the buyers' and sellers' myopicity. When an intermediary deviates, and quotes an off-equilibrium price, we assume that agents in one side of the market (say, buyers) take only into account the effect on the other agents on the same side of the markets (on the other buyers) and ignore the effect on the other side of the market (on the sellers). More specifically, consider an intermediary deviating to a lower price. This intermediatry attracts more buyers for a given number of sellers. Our assumption means that the sellers, too, are attracted to the deviating intermediary because of the lower price but not because of the greater number of buyers. Our short-cut in the modelling of price competition among intermediaries is comparable to the ones used in the literature, allowing us to avoid indeterminate outcomes or trivial outcomes such as a monopoly intermediary.

To make notation more compact we denote the distribution function of a Poisson-λ random variable by $F_\lambda(k) = \sum_{i=0}^{k} e^{-\lambda}\lambda^k/i!$. Assume that intermediaries ask price p. A buyer and seller who are paired then share equally the remaining surplus $1-p$. Denote the queue length at an intermediary by $\Omega = (1-z)/(2z)$. As the number of intermediaries is $2z$ both the buyers and the sellers face the same queue length Ω. A buyer, as well as a seller, expects market utility (MU) given by

$$\sum_{k=1}^{\infty} e^{-\Omega}\frac{\Omega^k}{k!}\left[F_\Omega(k-1) + \frac{k}{\Omega}\left(1 - F_\Omega(k)\right)\right]\frac{1-p}{2} = MU, \tag{6}$$

where the index k indicates the number of sellers that contact the intermediary. The first expression in the brackets in equation (6) is the probability that there are at most $k-1$ other buyers meaning that our buyer gets a good for certain. The second expression is the probability of trade when there are k or more other buyers.

If an intermediary deviates and asks price $\widetilde{p}$, the buyers' contact decisions lead to a queue length ω such that the buyers expect the market utility MU, and the same applies to the sellers. Because of the assumption that the buyers (sellers) take into account only the reactions of the other buyers (sellers) the condition that determines the relation of $\widetilde{p}$ and ω is given by

$$\sum_{k=1}^{\infty} e^{-\Omega}\frac{\Omega^k}{k!}\left[F_\omega(k-1) + \frac{k}{\omega}\left(1 - F_\omega(k)\right)\right]\frac{1-\widetilde{p}}{2} = MU. \tag{7}$$

Comparing equations (6) and (7) shows that, besides the charged price, only the terms in the square brackets differ. Totally differentiating equation (7) gives

$$\frac{\partial \omega}{\partial \widetilde{p}} = -\frac{\sum_{k=1}^{\infty} e^{-\Omega} \frac{\Omega^k}{k!} \left[F_\omega(k-1) + \frac{k}{\omega} \left(1 - F_\omega(k)\right) \right]}{\sum_{k=1}^{\infty} e^{-\Omega} \frac{\Omega^k}{k!} \frac{k}{\omega^2} \left(1 - F_\omega(k)\right) \left(1 - \widetilde{p}\right)}. \tag{8}$$

The deviating intermediary's objective is to choose $\widetilde{p}$ to maximize its expected profits, ie.,

$$\max_{\widetilde{p}} = \sum_{k=1}^{\infty} e^{-\omega} \frac{\omega^k}{k!} \left[\omega F_\omega(k-1) + k \left(1 - F_\omega(k)\right) \right] \widetilde{p}, \tag{9}$$

where the index in the sum keeps track of the number of sellers and the term in the square brackets displays the expected number of trades for a given number of buyers (k). The expression in the brackets is just the quantity that a firm with capacity k expects to sell (see, e.g., Godenhielm and Kultti, 2015); thus, the right-hand side of equation (9) gives the expected profits of a platform firm whose capacity is stochastic, depending on the number of sellers (with one unit of a good) attracted by the firm.

Using equation (8) to determine the first-order condition for problem (9) and evaluating it at $\widetilde{p} = p$ gives the equilibrium price

$$\begin{aligned} p^* = & \left(\sum_{k=0}^{\infty} e^{-\Omega} \frac{\Omega^k}{k!} \left(1 - F_\Omega(k+1)\right) \right) \Big/ \\ & \left(- \sum_{k=1}^{\infty} e^{-\Omega} \frac{\Omega^k}{k!} \left[\Omega F_\Omega(k-1) + k \left(1 - F_\Omega(k)\right) \right] \right. \\ & + \sum_{k=0}^{\infty} e^{-\Omega} \frac{\Omega^k}{k!} \left[\Omega F_\Omega(k) + (k+1) \left(1 - F_\Omega(k+1)\right) \right] \\ & \left. + \sum_{k=1}^{\infty} e^{-\Omega} \frac{\Omega^k}{k!} F_\Omega(k-1) + \sum_{k=0}^{\infty} e^{-\Omega} \frac{\Omega^k}{k!} \left(1 - F_\Omega(k+1)\right) \right). \end{aligned} \tag{10}$$

The equilibrium price p^* balances the competition for the buyers and sellers, and the profitability of intermediation given the somewhat myopic expectations of the agents. Equation (10) also shows that the solution with one intermediary cannot be an equilibrium; when Ω, the ratio of contacting buyers (or sellers) to intermediaries, approaches to infinity the price remains positive, meaning that a monopoly intermediary would certainly get larger profits than a buyer or a seller.

As the buyers and sellers are identical in this setting and the meeting rate is given by $\Omega = (1-z)/(2z)$, the equilibrium is determined by equating the buyers' (or sellers') and the intermediaries' expected utilities, ie., by

$$(11) \qquad \sum_{k=1}^{\infty} e^{-\Omega}\frac{\Omega^k}{k!}\left[F_\Omega(k-1) + \frac{k}{\Omega}\left(1 - F_\Omega(k)\right)\right]\frac{1-p^*}{2} = \sum_{k=1}^{\infty} e^{-\Omega}\frac{\Omega^k}{k!}\left[\Omega F_\Omega(k-1) + k\left(1 - F_\Omega(k)\right)\right]p^*,$$

where the left and right hand sides give the buyers' (expected) market utility (6) and the intermediary's expected profits (9), respectively, when evaluated at p^*.

Equations (10) and (11) jointly determine z^*, the equilibrium value of z. We find that z^* is (approximately) given by $z^* \approx 0.211$. Thus, approximately 79% of buyers and sellers contact the intermediaries and the meeting rate is $\Omega \approx 1.870$.

Result 3. *In equilibrium, some* 21% *of the buyers and sellers become intermediaries.*

We next determine the total number of trades, regarding it as the measure of efficiency of the economy. The profit, or the utility, of an intermediary is the expected number of trades multiplied by the price the intermediary gets for each trade. Consequently, just ignoring the price in the expression of the expected profit of an intermediary (in the right-hand side of equation (11)), we get the expected number of trades. Multiplying this number by the number of intermediaries gives the total number of trades as

$$\sum_{k=1}^{\infty} e^{-\Omega}\frac{\Omega^k}{k!}\left[\Omega F_\Omega(k-1) + k\left(1 - F_\Omega(k)\right)\right]2z^*.$$

This magnitude turns out to be apprriximately 0.475. Comparing this figure with the number of trades without intermediation 0.636 (Result 2) suggests that intermediation reduces welfare approximately by 25%.

Result 4. *With intermediation the gains from trade, or the number of trades, is approximately* 0.475*, which is about* 25% *less than without intermediation.*

Intermediaries reduce welfare in our model partly because they consume the resources of the economy; when a buyer or a seller decides to become an intermediary, there are fewer buyers or sellers in the economy. However, the reduction of gains from trade is not only the result of fewer buyers and sellers in the economy. Intermediation activity also attracts too many agents, failing to make the meetings more efficient: If all the intermediaries are removed from the economy, and the remaining buyers contact the remaining sellers directly as in section 2 the number of trades is approximately 0.499 or approximately 5% higher than with intermediaries.

4 Conclusion

We study the benefits and costs of intermediation in a directed search model where intermediation is a pure coordination or a platform service and costs of intermediation are endogenous. We find that intermedation reduces welfare by approximately 25%. The reason for the finding is that intermediation activity eats up the economy's resources and is so lucrative that it attracts far too many intermediaries, eliminating the gains from their coordination services. Our findings may provide some explanations for the wide spread popular discontent of intermediaries.

In a desire to focus on the benefits and costs of the intermediaries' coordination services, we have made a number of shorthcomings that should be addressed in the future work. Like many others before us, we are forced to simplify the price setting game between intermediaries. It is however, likely that our short-cut underestimates the profitability of intermediation and hence the welfare costs of intermediation are also biased downwards.

Following Spulber (1996) we assume that buyers and sellers must use intermediaries if they exist. Allowing for the co-existence of direct trade with intermediation would certainly be desirable in a future work.

Finally, we abstract a number of benefits and cost of intermediation studied in the literature. Our results suggest that competitive provision of coordination services is so inefficient that it cannot survive unless it performs some other functions. too. Thus, competitive coordination services like those in housing markets should be more about overcoming informational problems than about overcoming inefficiencies of meeting technologies.

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