Collaborative Housing and the Intermediation of Moral Hazard

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Abstract

This paper considers intermediation in a differentiated short-term housing market where heterogeneous agents may stay at a hotel or at one of several private hosts' properties, below or above hotel quality. The collaborative-housing market fails when agents' hidden actions are noncontractable. If expected liability is not excessive, a trusted intermediary can induce agents to exert first-best effort and fully insure the hosts' risks, without subsidizing the transactions. The intermediary can also extract the hosts' surplus if their outside option is zero; somewhat counterintuitively, the commission on either side of the transactions does not affect agents' equilibrium payoffs. The optimal commission structure makes direct transactions between hosts and renters unattractive.

1. Introduction

Demand for short-term accommodation has been traditionally served by hotels, inns, resorts, and the like, i.e., purpose-built commercial facilities. The latest explosion in intermediated private short-term housing suggests that there exists a significant latent supply of such accommodation from individual hosts, increasing the economic use of their own residential space; the latter is made available via usage agreements. In the absence of intermediaries, such direct collaborative-housing transactions usually do not take place, due to high matching costs and, more importantly, because of the significant moral-hazard issues embedded in the shared use of private space. While matching costs, commonly reduced by advertising platforms, newsgroups, and social networks, cannot be a significant barrier in a networked society, it is the persistent agency problem that has caused most collaborative-housing markets to fail until the recent emergence of specialized intermediaries such as AirBnB, Wimdu or 9flats. Using a simple model this paper shows that a trusted intermediary can enable short-term collaborative-housing transactions by implementing the first-best outcome of the underlying agency problem, thus effectively eliminating moral hazard.

A number of intrinsic reasons that may drive people to share their private property have been given by Belk (2007, 2010). Collaborative consumption becomes more prevalent in a society which is increasingly constrained by natural resources (Botsman and Rogers 2010; Schulist 2012). From an economic viewpoint, and in the absence of reputational concerns, sharing a resource becomes attractive when the expected benefits of the transaction outweigh the expected costs. For a potential host in a collaborative-housing agreement, expected benefits include economic rents that can be extracted from agents; expected disbenefits include upfront advertising expenditure to encourage matching with a renter, opportunity costs from foregone own use, and—most importantly—the cost of agency. The latter derives from the fact that the agent's actions, while enjoying the rented space are unobservable and thus largely noncontractable. To the best of our knowledge intermediated sharing, focusing on the economic incentives for collaborative usage, has not yet been discussed in the academic literature. In the Finance literature, intermediation has been considered with moral hazard on the part of the borrower who may be asked to place a bond (Marshall 1976; Kihlstrom and Matthews 1990).

In our model, the renter (agent) is asked to make a deposit and, in the case of a claim by the host, to pay an amount equal to the claim plus a penalty rate to the intermediary, up to a total of the deposit. The host claims the full damage from the intermediary, which (after verification) in turn pays all but a pre-agreed deductible. To facilitate the transaction, the intermediary charges a percentage of the nominal transaction price both to the renter and the host. Given a competitive outside market for hotels, hosts provide imperfect differentiated substitutes and choose their prices in equilibrium so as to balance out the intermediary's surcharges for the agents, whose payoffs remain unaffected as long as all hosts stay in the market. We show that the intermediary can fully cover the hosts' claims (without deductible) and also provide first-best (i.e., socially optimal) incentives for the renters to exert care. In other words, the intermediary induces first-best agent behavior, equivalent to the hosts' continued use of the space. At the same time,

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the intermediary is able to extract a portion of the hosts' surplus that is limited only by their outside option.

Our work is related to recent contributions in the literature on two-sided markets (Biglaiser and Friedman 1994; Armstrong 2006; Rochet and Tirole 2006). Roger and Vasconcelos (2012) examine platform pricing and moral hazard in a dynamic setting with reputation, where sellers can be induced by a two-part tariff, including a fixed registration fee, to take a favorable high-effort action. In that setting the elimination of the moral-hazard problem depends on the availability of the fixed participation fee, which allows sellers effectively to place a bond. In our static model the intuition is similar, only that in the case of temporary housing the moral hazard lies with the buyer (renter), who is therefore asked to place a bond in the form of a deposit. Because of the embedded insurance problem in this setting, the novelty of our study lies not in confirming that placing a bond is effective in eliminating moral hazard, but in solving the particulars of the business problem with an embedded actuarial insurance problem using a surcharge and in showing how one can effectively separate the agency problem in a budget-neutral way from the rent-extraction (or profit maximization) problem.

The remainder of this paper is organized as follows: Section 2 introduces the model for an intermediated market for short-term collaborative housing and provides simple equilibrium results. Section 3 shows how the intermediary can eliminate moral hazard in collaborative-housing transactions. In Section 4, we discuss the intermediary's profit-maximization problem. Section 5 concludes.

2. Model

A potential renter (agent) has a marginal utility $\theta \in [0,1]$ for staying at a place of perceived quality q; any stay is for a time period of unit length (e.g., one day). For simplicity, we assume that all renters perceive qualities in the same way (so we can restrict attention to vertical differentiation) and that their types θ are uniformly distributed on the interval $[0,1]$. Given a matching probability $\beta \in (0,1]$ for an intermediated private transaction,[1] a renter of type θ has expected payoff

$$u_R = \beta\left(\theta q - (1+r)p - \varphi\right) + (1-\beta)\left(\theta q_0 - p_0\right),$$

where (p,q) and (p_0,q_0) are the price-quantity-tuples for stays at a private property or a hotel, respectively, and r is a surcharge rate (fixed by the intermediary) over the posted price p (so the renter's total monetary transfer is $(1+r)p$, excluding a possible deposit). The nonnegative constant φ denotes an expected agency cost for the renter in a collaborative-housing agreement, to be specified in Section 3. To avoid uninteresting complications, we assume that the hotel market is competitive and undifferentiated with $q_0 > 0$. Further, there are two potential hosts (1 and 2) with properties of qualities

$$q_1 = q_0 - \varepsilon \quad \text{and} \quad q_2 = q_0 + \varepsilon,$$

where $\varepsilon < q_0$, so private properties are considered by the renter akin to a mean-preserving spread of hotels: some private properties are better, some are worse, with a random selection of the two being of comparable quality. This assumption seeks to eliminate any intrinsic advantage or disadvantage of the collaborative-housing market; it can be easily relaxed.[2] Given the properties of qualities $q \in \{q_1, q_2\}$ at prices $p \in \{p_1, p_2\}$, one obtains the marginal renter types:

$$\theta_{20} = \frac{(1+r)p_2 - p_0 + \varphi}{\varepsilon},$$

indifferent between property 2 and a hotel, and

$$\theta_{10} = \frac{p_0 - (1+r)p_1 - \varphi}{\varepsilon},$$

indifferent between property 1 and a hotel. On the other hand, given that the intermediary appropriates a portion $h \in [0,1)$ of the nominal transaction price p_i, host $i \in \{1,2\}$ has expected payoff π_i (conditional on matching with a renter), where

$$\begin{aligned}\pi_1 &= (1-\theta_{20})\left((1-h)p_2 - \delta\right)\\ &= \left(1 - \frac{(1+r)p_2 - p_0 + \varphi}{\varepsilon}\right)\left((1-h)p_2 - \delta\right),\end{aligned}$$

and

$$\begin{aligned}\pi_2 &= \theta_{10}\left((1-h)p_1 - \delta\right)\\ &= \left(\frac{p_0 - (1+r)p_1 - \varphi}{\varepsilon}\right)\left((1-h)p_1 - \delta\right).\end{aligned}$$

The nonnegative constant δ denotes an expected agency cost for each host in a collaborative-housing agreement, to be specified in Section 3.

[1] As long as the intermediated matching probability β does not vanish, it is irrelevant for our main results. We generally assume a sellers' market where prospective renters contact hosts, who in turn approve a transaction, as it is common practice for current collaborative-housing intermediaries. At the end of Section 4, we show that the intermediary can capitalize on that fact that its platform increases the matching probability (cf. Corollary 2). For our main analysis we first neglect this effect.

[2] More precisely, we assume that there are two types of hosts, or alternatively, that either host can accommodate all of the prevailing demand.

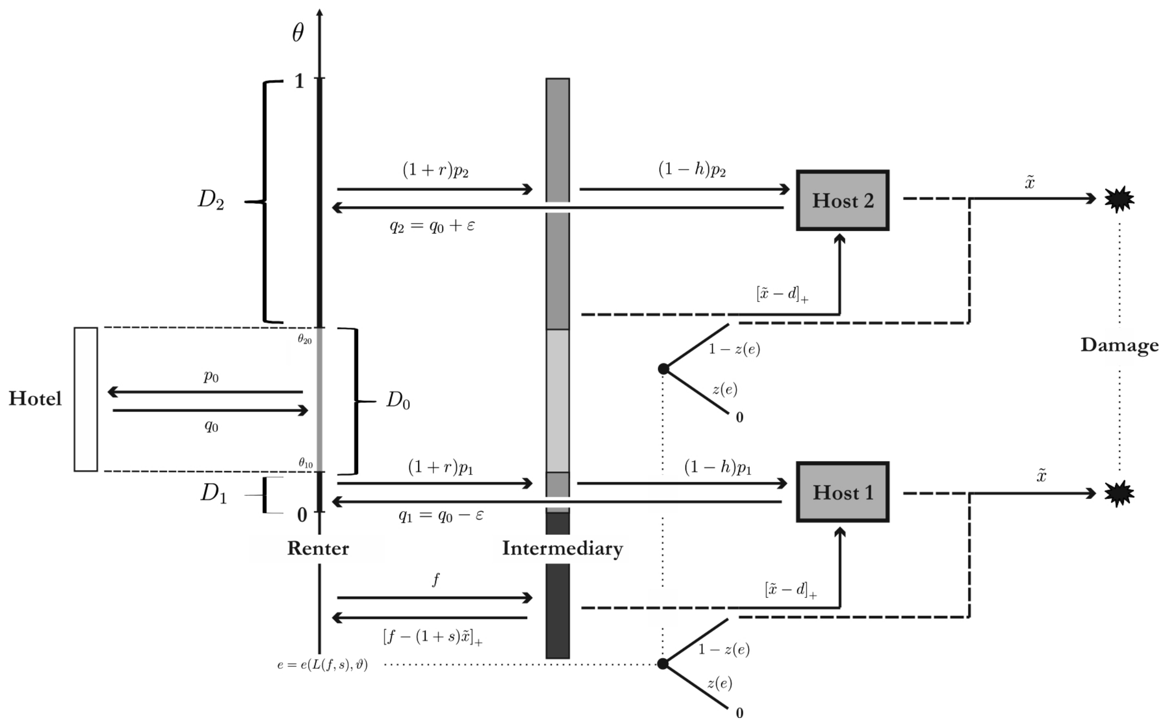

Figure 1: Model Overview.

The timing of the game is such that the intermediary first specifies the rate structure (h, r) as well as the terms pertaining to the moral-hazard side of the rental agreement, which fix δ and φ. Then the hosts choose their prices p_1 and p_2. Lastly, the consumers decide about participation (resulting in the marginal types above) and their efforts to mitigate any potential moral hazard. Figure 1 provides a model overview, including relevant notation, some of which is introduced in the next section.

Lemma 1. *The hosts' unique Nash equilibrium prices p_1^* and p_2^* are given by*

$$p_1^* = \frac{1}{2}\left(\frac{p_0-\varphi}{1+r}+\frac{\delta}{1-h}\right),$$
$$p_2^* = \frac{1}{2}\left(\frac{p_0+\varepsilon-\varphi}{1+r}+\frac{\delta}{1-h}\right),$$

assuming that both of their market segments are active.

Proof. The best-response functions for the two hosts are affine in their respective prices; the unique Nash equilibrium obtains in a standard manner. □

Based on the equilibrium prices in Lemma 1, the marginal types in equilibrium are

$$\theta_{20}^* = \frac{1}{2} - \frac{1}{2\varepsilon}\left(p_0 - \varphi - \rho\delta\right),$$

and

$$\theta_{10}^* = \frac{1}{2\varepsilon}\left(p_0 - \varphi - \rho\delta\right),$$

where

$$\rho = \frac{1+r}{1-h} \geq 1$$

denotes the "commission ratio" (or, more precisely, the price ratio) between the two sides of the market.

Lemma 2. *All market segments are active if and only if $p_0 \in \varphi + \rho\delta + (0, \varepsilon/2)$.*

Proof. The hosts' equilibrium demands are

$$D_1^* = \frac{1}{2\varepsilon}\left(p_0 - \varphi - \rho\delta\right)$$

and

$$D_2^* = \frac{1}{2} + \frac{1}{2\varepsilon}\left(p_0 - \varphi - \rho\delta\right),$$

respectively. The equilibrium demand for hotels is

$$D_0^* = 1 - (D_1^* + D_2^*) = \frac{1}{2} - \frac{1}{\varepsilon}\left(p_0 - \varphi - \rho\delta\right).$$

It is straightforward to verify that all of these demands are positive if the above condition is satisfied. □

For all properties to coexist in equilibrium, hotels as the prevalent outside option must be priced taking into account both the effective agency cost $\alpha = \varphi + \rho\delta$ of a collaborative-housing transaction and the quality dispersion ε.

Lemma 3. *Provided all market segments are active, the hosts' equilibrium profits are*

$$\pi_1^* = \frac{(p_0 - \varphi - \rho\delta)^2}{4\rho\varepsilon} \quad \textit{and} \quad \pi_2^* = \frac{(p_0 + \varepsilon - \varphi - \rho\delta)^2}{4\rho\varepsilon},$$

respectively.

Proof. The result is obtained by computing $\pi_i^* = ((1-h)p_i^* - \delta)D_i^*$, for $i \in \{1, 2\}$, using Lemma 1 and Lemma 2. □

The hosts' payoffs are decreasing in the effective agency cost; even if their own agency cost δ vanishes (which happens when the intermediary eliminates moral hazard, cf. Section 3), the hosts' payoffs are also decreasing in the commission ratio ρ. As hotels in the area become more expensive, that is when p_0 increases, the rents that hosts can extract from renters, all else equal, also increase.

Lemma 4. *Provided all market segments are active, the intermediary's payoff is*

$$\pi_I = \frac{\rho - 1}{4\rho\varepsilon}\left((p_0 - \varphi - \rho\delta)^2 + (p_0 + \varepsilon - \varphi - \rho\delta)^2\right) - \Delta,$$

where Δ is the intermediary's agency-related cost of guaranteeing the transaction.

Proof. When choosing the commission structure (h, r), the intermediary's payoff becomes

$$\pi_I = (h + r)\left(p_1^* \cdot D_1^* + p_2^* \cdot D_2^*\right) - \Delta,$$

which, after simplification, completes the proof. □

In the next section, we show that the agency-related intermediation cost Δ, which consists of the intermediary's capital at risk R (conditional on damage) times the agent-controlled probability of damage (see Section 3), can in fact be eliminated; the same holds true for the agency-related hosting cost δ. For this, the agent needs to internalize the cost of the effective damage if it is not prevented by a sufficient (i.e., first-best) effort in taking care of the rented property.

3. Elimination of Moral Hazard

The renter of a private property is subject to moral hazard because his actions, here measured in terms of effort to prevent damage (including excessive uncleanliness), are not contractable. Let $z(e) = e \in [0, 1]$ be the probability of no damage, depending on the renter's effort e. The renter has a cost of effort $C(e, \vartheta) = \vartheta e^2/2$, where ϑ is the (maximum) marginal cost of effort (at $e = 1$).[3] In general, the agents are heterogeneous with respect to their effort-cost parameter ϑ; the corresponding cumulative distribution function is $G(\vartheta)$. To avoid saturation effects, we assume that any renter would find it unacceptable to invest as much effort to completely prevent the expected damage μ because

$$\vartheta > \mu,$$

that is, the support of G is assumed be located on the right of μ. This assumption avoids saturation of $z(e)$ (at 1) by assuming that agents are unable or rather unwilling to spend all their available time on damage prevention. With probability $1 - z(e)$ the renter causes an uncertain damage $\tilde{x}$ according to the Pareto distribution, $F(x) = 1 - (m/x)^\kappa$, with realizations x in $[m, \infty)$. The shape parameter $\kappa > 1$ determines the thickness of the tail of the distribution (thickness decreasing in κ), while $m > 0$ denotes the minimum damage that a host would start worrying about. The expected damage, conditional on its occurrence is

$$\mu = \int_m^\infty x\, dF(x) = \left(\frac{\kappa}{\kappa - 1}\right) m.$$

Given a deposit $f > 0$ and a surcharge rate s in case of damage, the renter's expected agency cost at the optimal effort $e^*(L(f, s), \vartheta) = \min\{1, L(f, s)/\vartheta\}$ is[4]

$$\begin{aligned}
&\min_{e \in [0,1]} \left\{(1 - e)L(f, s) + \vartheta e^2/2\right\} \\
&\qquad = \left[1 - \frac{L(f, s)}{2\vartheta}\right]_+ L(f, s),
\end{aligned}$$

where the expected liability amounts to

$$\begin{aligned}
L(f, s) &= \int_0^\infty \min\{(1 + s)x, f\}\, dF(x) \\
&= (1 + s)\int_m^{f/(1+s)} x dF(x) \\
&\quad + f \cdot (1 - F(f/(1 + s))) \\
&= (1 + s)\mu\left(1 - \frac{1}{\kappa}\left(\frac{(1 + s)\,m}{f}\right)^{\kappa - 1}\right).
\end{aligned}$$

As long as $L(f, s) \le \mu$, the expected agency cost is

$$\begin{aligned}
\varphi(f, s) &= \int_{\vartheta_0}^\infty \left[1 - \frac{L(f, s)}{2\vartheta}\right]_+ L(f, s) dG(\vartheta) \\
&= \left(1 - \frac{\gamma L(f, s)}{2}\right) L(f, s),
\end{aligned}$$

where[5]

$$\gamma = \int_0^\infty \frac{dG(\vartheta)}{\vartheta} < \frac{1}{\mu}.$$

[3] To be clear, $\vartheta = \frac{\partial}{\partial e}\Big|_{e=1} C(e, \vartheta) = \max\{C_e(e, \vartheta) : e \in [0, 1]\}$.

[4] By definition, $[y]_+ = \max\{0, y\}$ for all $y \in \mathbb{R}$.

[5] The heterogeneity in the agents' cost types ϑ is an inessential model feature. What matters is that γ, which by Jensen's inequality exceeds $1/\int_0^\infty \vartheta dG(\vartheta)$, is less than $1/\mu$, in view of avoiding a situation where agents find it too easy to skirt any risk of damage.

A host's expected agency cost δ depends on the agent's equilibrium effort $e^*(L(f,s),\vartheta)$ and the deductible d; hence, provided that $f \geq m$,

$$\begin{aligned}\delta(d,f,s) &= (1-\gamma L(f,s))\int_f^{f+d}(x-f)\,dF(x)\\ &= (1-\gamma L(f,s))\left(\frac{\mu}{\kappa}\right)\left(\frac{m}{f}\right)^{\kappa-1}\times\\ &\quad\times\left(1-\left(\frac{f}{f+d}\right)^{\kappa-1}\right).\end{aligned}$$

Consider now the intermediary's expected cost of insuring the transaction, assuming that the renter's expected liability (conditional on damage) does not exceed expected damages μ,

$$\Delta(f,s) = (1-\gamma L(f,s))R(d,f,s),$$

where, given any choice of $(d,f,s) \geq 0$, the expected capital at risk is

$$\begin{aligned}R(d,f,s) &= -\int_m^{\frac{f}{1+s}} sx\,dF(x)\\ &\quad -\int_{\frac{f}{1+s}}^{f}(f-x)\,dF(x)\\ &\quad +\int_{f+d}^{\infty}(x-(d+f))\,dF(x)\\ &= -s\mu+\left(\frac{\mu}{\kappa}\right)\left(\frac{m}{f}\right)^{\kappa-1}\times\\ &\quad\times\left((1+s)^\kappa+\left(\frac{f}{f+d}\right)^{\kappa-1}-1\right).\end{aligned}$$

Figure 2 shows how the cost of an actual damage x is split up among the host, renter, and intermediary, as a function of (d,f,s). To find the best way for the intermediary to eliminate the moral hazard in renter-host transactions, note first that the renter's expected liability $L(f,s)$ is independent of the host's deductible d. On the other hand, the host's agency cost δ can only vanish for $d=0$. Next, we observe that the renter cannot be incentivized properly if his damage liability is larger than the actual expected damage μ. Inflating the agent's liability would only lead to some agents not participating because of moral-hazard concerns, despite the potential gains from trade. The following result provides the only suitable deductible-free policy for the intermediary.

Theorem 1. *There exists a unique deductible-free policy (d^*,f^*,s^*) with $d^*=0$ and $L(f^*,s^*) \leq \mu$ that minimizes the intermediary's capital at risk. At this policy, the deposit equals the expected damage (i.e., $f^*=\mu$), the surcharge factor $1+s^*$ is equal to $\mu/m = \kappa/(\kappa-1)$ (i.e., $s^*=1/(\kappa-1)$), and the capital at risk vanishes:*

$$0 = R(0,f^*,s^*) = \min\{R(0,f,s) : L(f,s) \leq \mu\}.$$

Finally, the agent's expected damage liability is $L(f^*,s^*)=\mu$ and his effort first-best.

Proof. The intermediary's deductible-free capital at risk,

$$R(0,f,s) = \left(\frac{(1+s)^\kappa}{\kappa}\left(\frac{m}{f}\right)^{\kappa-1}-s\right)\mu,$$

is decreasing in the deposit f and strictly convex in s. For any given $f \geq m$ (always feasible because $\mu > m$ for all $\kappa > 1$) it is minimized for a surcharge rate

$$\hat{s}(f) = \frac{f}{m}-1,$$

so

$$\begin{aligned}R(0,\hat{s}(f),f) &= \mu\left(1-\frac{f}{m}\frac{\kappa-1}{\kappa}\right)\\ &= \mu\left(1-\frac{f}{\mu}\right) \leq R(0,f,s),\end{aligned}$$

for all $f \geq m$. The capital at risk $R(0,\hat{s}(f),f)$ is decreasing in f, which yields the optimal deposit,

$$f^* = \max\{f \in [m,\mu] : L(f,\hat{s}(f)) \leq \mu\} = \mu,$$

since $L(f,\hat{s}(f)) = f$ for all $f \geq m$. We obtain the optimal surcharge rate,

$$s^* = \hat{s}(f^*) = \frac{\kappa}{\kappa-1}-1 = \frac{1}{\kappa-1},$$

which implies that $R(0,f^*,s^*)=0$ and $L(f^*,s^*)=\mu$. □

To eliminate moral hazard, the intermediary asks a renter to deposit the expected damages μ upfront and adds a penalty rate if portions of that amount need to be paid out to satisfy (legitimate) claims by the host. The following result is obtained as an immediate consequence of Theorem 1.

Corollary 1. *The policy $(d^*,f^*,s^*) = (0,\mu,1/(\kappa-1))$ is "moral-hazard-free" in the sense that δ and Δ both vanish, and φ corresponds (approximately) to the ongoing damage cost experienced by the hosts occupying their own property,[6] i.e., in the absence of collaborative housing, $\varphi^* = \varphi(0,\mu,1/(\kappa-1)) = (1-(\gamma/2)\mu)\mu$.*

[6] We ignore the fact that a renter generally lacks the host's experience in navigating the property and thus may in reality have a higher cost to prevent damage than the host.

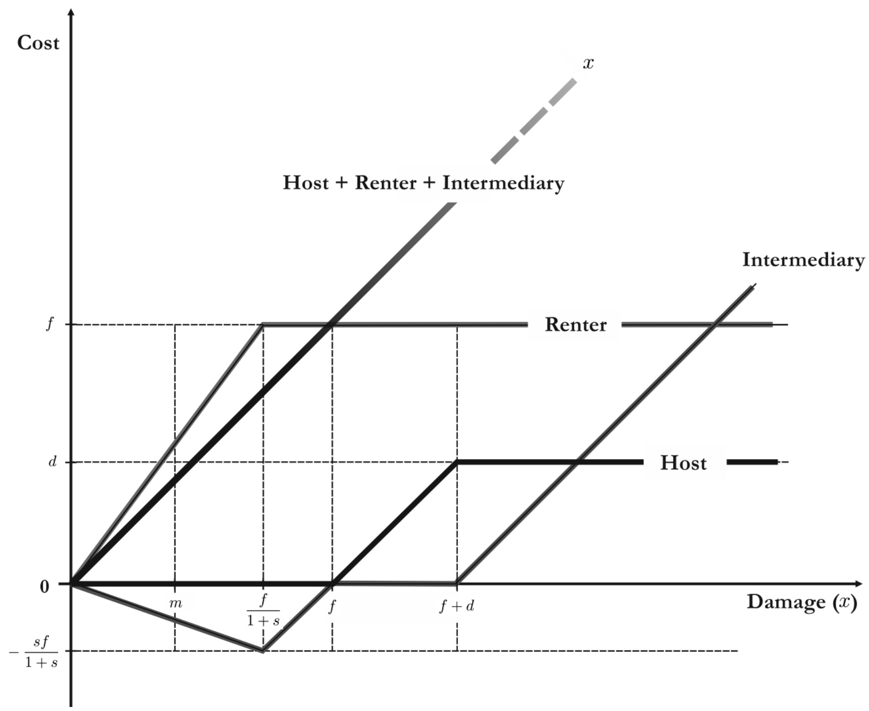

Figure 2: Cost of damage x shared by host, renter, and intermediary, as a function of the deductible d, the deposit f, and the surcharge rate s.

The first-best effort $e^{\text{FB}}(\vartheta) = \min\{\mu/\vartheta, 1\}$ is induced for all cost types ϑ. By eliminating the moral-hazard issue, the intermediary effectively decouples its profit-maximization problem from the rent-extraction problem. Although it is conceivable that a small profit could be made from providing an insurance service against moral hazard (e.g., by setting $d > 0$), this effectively reduces the hosts' surplus and thus allows for less rent-extraction via the two-sided commission structure (h, r), which is discussed next.

4. Profit Maximization

With the choice of $(d, f, s) = (d^*, f^*, s^*)$ specified in Theorem 1, by Corollary 1 it is $(\delta, \Delta) = 0$. Before seeking to optimize the intermediary's commission structure (h, r), we first note the invariance of demand in equilibrium.

Lemma 5. *For $(d, f, s) = (0, \mu, 1/(\kappa-1))$, the equilibrium demands D_0^*, D_1^*, D_2^* do not depend on the commission ratio ρ.*

Proof. This result follows directly from Lemma 2 when setting $\delta = 0$. $\square$

Interestingly, despite the fact that demands are effectively invariant with respect to changes in the commission structure, prices do decrease when the renter's rate r is increased, so that the intermediated end price stays constant.

Lemma 6. *For $(d, f, s) = (0, \mu, 1/(\kappa - 1))$, the amounts paid by consumers to the intermediary do not depend on the commission structure: $(1 + r)p_1^* \equiv (p_0 - \varphi^*)/2$ and $(1 + r)p_2^* \equiv (p_0 + \varepsilon - \varphi^*)/2$.*

Proof. This result follows directly from Lemma 1 when setting $\delta = 0$. $\square$

The last two results together demonstrate that by changing the commission structure all the intermediary can do is to extract surplus from the hosts. While this may initially appear counterintuitive, it is in fact unsurprising. After having eliminated the moral-hazard problem, conditional on the parties having matched, the intermediary cannot provide any further improvement of the transaction. Hence, its mere presence cannot increase the total payments from the agents. In the absence of outside options for the hosts, all their surplus can be extracted in the limit (i.e., $\rho \nearrow \infty$), for example, as $h \nearrow 1$.

Lemma 7. *In the absence of outside options for the hosts, the intermediary's profit π_I is increasing in the commission ratio ρ. For $(d, f, s) = (0, \mu, 1/(\kappa - 1))$ and provided all market segments are active, the inter-*

mediary can extract full surplus from the hosts,

$$\lim_{\rho\to\infty} \pi_I = [\pi_1^* + \pi_2^*]|_{\rho=1}$$
$$= \frac{1}{4\varepsilon}\left((p_0 - \varphi^*)^2 + (p_0 + \varepsilon - \varphi^*)^2\right),$$

which can be implemented by setting $h^* = 1$.

Proof. The assertions follow directly from Lemma 3 and Lemma 4. □

In actuality, the hosts' outside option consists in ignoring moral hazard and transacting directly with renters; this limits the commission ratio $\rho = (1 + r)/(1 - h)$ the intermediary can charge. Furthermore, the commission structure (h, r) needs to ensure that renters do not find direct transactions beneficial. These two conditions together determine the intermediary's optimal commission structure (h^*, r^*).

Theorem 2. *For* $(d, f, s) = (0, \mu, 1/(\kappa - 1))$*, the intermediary's optimal commission ratio,*

$$\rho^* = \left(\frac{p_0 + \varepsilon - \varphi^*}{p_0 + \varepsilon - \mu}\right)^2 > 1,$$

has an optimal commission structure (h^*, r^*)*, where*

$$h^* = 1 - \frac{1}{p_0 + \varepsilon + \varphi^*}\left(\frac{p_0 + \varepsilon}{\rho^*} - \mu\right) \in (0, 1),$$
$$r^* = \frac{\rho^*\mu - \varphi^*}{p_0 + \varepsilon} > 0.$$

Proof. As noted in Lemma 7, the intermediary's profit is increasing in ρ when the hosts do not have any outside options to earn economic rents on their private space. For both hosts' direct-transaction profits to be smaller than under an intermediated transaction, the commission ratio needs to stay finite. Indeed,

$$\hat{\pi}_1 = \frac{(p_0 - \mu)^2}{4\varepsilon} \le \frac{(p_0 - \varphi^*)^2}{4\rho\varepsilon} = \pi_1^*$$

and

$$\hat{\pi}_2 = \frac{(p_0 + \varepsilon - \mu)^2}{4\varepsilon} \le \frac{(p_0 + \varepsilon - \varphi^*)^2}{4\rho\varepsilon} = \pi_2^*$$

are both satisfied if and only if

$$\rho \le \left(\frac{p_0 + \varepsilon - \varphi^*}{p_0 + \varepsilon - \mu}\right)^2 = \rho^*.$$

The optimal commission ratio ρ^* guarantees that none of the hosts would want to deviate to an equilibrium with direct transactions. In addition, the intermediary needs to discourage renters from seeking a direct transaction by keeping their total cost, $(1 + r)p + \varphi$, equal or below to what they can expect in a direct transaction. This amounts to the conditions

$$(1 + r)\hat{p}_1 + 0 = \left(\frac{1 + r}{2}\right)\left(p_0 + \frac{\mu}{1 - h}\right)$$
$$\ge \frac{p_0 + \varphi^*}{2}$$
$$= (1 + r)p_1^* + \varphi^*$$

and

$$(1 + r)\hat{p}_2 + 0 = \left(\frac{1 + r}{2}\right)\left(p_0 + \varepsilon + \frac{\mu}{1 - h}\right)$$
$$\ge \frac{p_0 + \varepsilon + \varphi^*}{2}$$
$$= (1 + r)p_2^* + \varphi^*,$$

of which the second is more restrictive. Both conditions are satisfied when

$$r \le r^* = \frac{p_0 + \varepsilon + \rho^*\mu}{p_0 + \varepsilon + \varphi^*} - 1 \ge 0,$$

where r^* is the maximum renter's commission. Since $\rho^* = (1 + r^*)/(1 - h^*)$, the optimal host's commission is

$$h^* = 1 - \frac{1 + r^*}{\rho^*}$$
$$= 1 - \left(\frac{p_0 + \varepsilon - \mu}{p_0 + \varepsilon - \varphi^*}\right)^2 \left(\frac{p_0 + \varepsilon}{p_0 + \varepsilon + \varphi^*}\right)$$
$$- \left(\frac{\mu}{p_0 + \varepsilon + \varphi^*}\right).$$

To see that $0 < h^* < 1$, note first that because $1 + r^* = (1 - h^*)\rho^*$, it is

$$\rho^* = \left(1 - h^* - \frac{\mu}{p_0 + \varepsilon + \varphi^*}\right)^{-1}\left(\frac{p_0 + \varepsilon}{p_0 + \varepsilon + \varphi^*}\right).$$

For $h^* = 0$, it is easy to show that the right-hand side is less than ρ^*; for $h^* = 1 - \frac{\mu}{p_0+\varepsilon+\varphi^*}$, it diverges and thus exceeds ρ^*. Hence,

$$0 < h^* < 1 - \frac{\mu}{p_0 + \varepsilon + \varphi^*} < 1,$$

which completes our proof. □

When renter and host transact directly, the renter exerts no effort (so $\varphi = 0$), no commission is charged on either side of the market (so $\rho = 1$), and the host bears the expected damage cost (so $\delta = \mu$). In Section 2 we introduced $\alpha = \varphi + \rho\delta$ as the total cost of agency. With intermediary this cost, at $\alpha^* = \varphi^*$, is less than its value without intermediary, $\hat{\alpha} = \mu$, i.e.,

$$\alpha^* = \mu - \frac{\gamma\mu^2}{2} < \mu = \hat{\alpha}.$$

Moreover, in direct transactions the demand for collaborative housing decreases because (cf. proof of Lemma 2)

$$\hat{D}_i - D_i^* = -\frac{\hat{\alpha} - \alpha^*}{2\varepsilon} = -\frac{\gamma\mu^2}{4\varepsilon} < 0,$$

where $\hat{D}_i$ denotes the demand for host $i \in \{1, 2\}$ without intermediary. Both demands decrease by the same amount, so that the already smaller demand for host 1 ($D_1^* < D_2^*/2$) is, in terms of percentage decrease, much more affected than host 2. This is driven by the simplifying assumption that the damage is independent of the property type, thus disadvantaging low-quality collaborative-housing transactions. Correspondingly the demand for hotels increases by $\gamma\mu^2/(2\varepsilon)$.

When accounting for a contribution to increasing the matching probability (in addition to the value generated by eliminating moral hazard), say, from $\hat{\beta}$ for direct matching to $\beta^* \geq \hat{\beta}$, the intermediary's rent-extraction capability is higher than discussed so far.

Corollary 2. *Given a matching enhancement with* $0 < \hat{\beta} \leq \beta^* \leq 1$, *the intermediary's optimal commission ratio increases to* $(\beta^*/\hat{\beta})\rho^*$ *from the optimal commission ratio* ρ^* *without matching enhancement in Theorem 2.*

Proof. The matching-enhanced optimal commission ratio obtains from the conditions $\hat{\beta}\hat{\pi}_1 \leq \beta^*\pi_i^*$ for both hosts $i \in \{1, 2\}$. Note that for $\hat{\beta} = \beta^*$ these conditions specialize to what was discussed at the beginning of the proof of Theorem 2. □

5. Conclusion

Markets for collaborative housing pre-date electronic intermediaries. For instance, in Scotland widespread signs with "bed-and-breakfast" next to private homes advertise hosts' willingness to let individuals stay in their private space. In those markets, usually in small communities, the probability of matching is significant and, more importantly, good behavior by the guests is engendered by the accountability of regional travellers. This model does not scale well to cities and even less to metropolitan areas where the expected damage costs are higher and renters are international. Furthermore, the probability of matching without the help of an intermediary becomes prohibitively low.

We have shown that a trusted intermediary can enable collaborative-housing transactions in environments with moral hazard, implementing first-best actions by renters and fully insuring hosts (with zero deductible) at a balanced budget. The main idea is to surcharge renters in case of damage, up to their full deposit in the amount of the expected damage cost, should a mishap occur. In our model, the intermediary's ability to extract rents is limited only by the hosts' ability to transact directly with renters. The optimal commission structure discourages both sides of the transaction, renters and hosts, from seeking a direct-transaction equilibrium. In practice, however, repeat transactions on the intermediary's platform (and the resulting trust) may encourage parties to circumvent the fee structure, which may prompt the intermediary to design an augmented commission structure that takes the parties' reputations and bilateral familiarity into account. A formal treatment of such reputation-dependent pricing in a dynamic setting is left as an interesting open problem for future research. Another important point not touched by our analysis is that the intermediary's capacity of rent extraction is limited in general by other intermediaries. The effects of competition between several intermediaries depend on the degree of similarity between them; their rents will in any case be reduced unless they are able to implicitly collude.

Collaborative housing has public-policy implications because enabling private transactions of this type leads to a more efficient use of existing assets, reducing the frictional costs of travel on society.[7] At the very least, collaborative housing can serve as a buffer in times of peak demand for temporary accommodations (e.g., during holiday seasons), thus discouraging the creation and maintenance of excess hotel space, resulting in a more efficient use of economic resources overall. By eliminating moral hazard, the intermediary enables the realization of gains from trade in the economy, which is welfare-improving from a social point of view.

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