Price Coherence and Adverse Intermediation*

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Abstract

Suppose an intermediary provides a benefit to buyers when they purchase from sellers using the intermediary's technology. We develop a model to show that the intermediary will want to restrict sellers from charging buyers more for transactions it intermediates. We show that this restriction can reduce consumer surplus and welfare, sometimes to such an extent that the existence of the intermediary can be harmful. Specifically, lower consumer surplus and welfare result from inflated retail prices, over-investment in providing benefits to buyers, and excessive adoption of the intermediaries' services. Competition among intermediaries intensifies these problems by increasing the magnitude of their effects and broadening the circumstances in which they arise. We show similar results arise when intermediaries provide matching benefits, namely recommendations of sellers to buy from. We discuss applications to travel reservation systems, payment card systems, marketplaces, rebate services, search engine advertising, and various types of brokers and agencies.

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1 Introduction

Myriad sellers have long chosen to provide their goods and services via intermediaries, which often serve as distributors, brokers, payment processors, or other facilitators. Ideally, intermediaries have a genuine advantage—perhaps superior knowledge of local conditions, lower costs, or a complementary

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benefit to better serve buyers' needs. That said, certain intermediaries' pricing policies can lower consumer surplus below the level that would result without those constraints, and in some cases can even reduce welfare. Moreover, intermediaries can thrive even when they offer little or no actual value due to a market failure caused by the structure of the relationship between buyer, seller, and intermediary.

Specifically, a purchase via an intermediary is often constrained to occur at the same price as a purchase directly from the seller (or through another competing intermediary)—preventing the buyer from considering the cost of the intermediary's service. We call this constraint "price coherence," following Frankel (1998) who used this term in the context of payment cards. (In Section 2 we explore the sources of this constraint, which are often contractual restrictions that intermediaries impose implicitly or explicitly, though can also include regulation, industry custom, or cognitive biases.) The resulting outcome is not welfare-maximizing and may even be inefficient: buyers end up choosing to use an intermediary's service even though the costs of the service exceed the benefits created by the service. Even intense competition between intermediaries may not solve this market failure.

In this paper, we first characterize selected markets where price coherence arises. Some prior work studies price coherence in payment card markets, and other work examines markets with rules that are, in our framework, similar. We join and generalize this previous literature, noting commonalities among seemingly-diverse markets. For example, we show how the features found in the payments literature map to similar rules, restrictions, and practices in other intermediated markets including travel reservations, marketplaces, and certain types of insurance and financial services.

We then develop a simple model of intermediation in markets with price coherence. We first consider a benchmark setting in which there is a single intermediary, two differentiated but competing sellers and a continuum of buyers. The intermediary can invest in providing some benefit to buyers when they use its service to purchase from sellers. The intermediary always prefers to impose price coherence—to prevent buyers from paying more when they buy through the intermediary versus when they buy directly. Because buyers that join the intermediary enjoy the benefit of using the intermediary's service without facing a differential cost, the intermediary is able to raise its fee to sellers. In response, sellers raise prices to all buyers, thereby reducing consumer surplus. Furthermore, with price coherence, the intermediary can sometimes sustain an equilibrium in which some buyers and both sellers join and use the intermediary even when the intermediary is inefficient, reducing welfare compared to the case without the intermediary. Removing the price coherence constraint raises consumer surplus and sometimes welfare. We then extend the model to allow for competition between intermediaries.

We find that, far from curing the problems, competition between intermediaries causes the effects to become larger and to occur more broadly. We also extend the model to consider an intermediary with superior information about which seller is best for a given buyer—but even with that advantage, on our assumptions, the intermediary still harms consumers.

To illustrate the mechanism causing market failure under price coherence, it may be helpful to consider a simple numerical example. Suppose a large number of buyers each seek to buy a single unit of a good from one of two competing but differentiated sellers. A buyer can buy directly from a seller, in which case the good has a \$1 value to the buyer. Alternatively, a buyer can buy via an intermediary M who adds some benefit yielding total value \$1.30 to the buyer. A buyer incurs a transaction cost of \$0.15 to join M. M incurs a cost of \$0.20 to provide the added benefit to each buyer.

First, consider the standard case in which a seller can set a different price for a buyer who buys directly from the seller versus a buyer who buys through M. Suppose M tries to recover its costs by charging a seller \$0.20 for each sale it facilitates. For any buyer who buys through M, a seller passes along the \$0.20 greater cost resulting from sales via M. A consumer buying through M enjoys the \$0.30 benefit but pays a \$0.20 higher price plus incurs a \$0.15 transaction cost. Considering the net cost, all buyers prefer to buy directly, so no buyers join M and no sales occur via M.

Now suppose a seller who sells via M is constrained to charge the same price to buyers who buy through M as to buyers who buy directly. With this constraint in mind, suppose M charges a seller \$0.25 for each sale it facilitates (but charges nothing to buyers). Consider the resulting incentives. A buyer who declines to join M would pay the same price but give up M's benefit, so all buyers join M. Each seller is willing to pay M's fee of \$0.25 because refusing to pay would cause the seller's buyers to lose access to the added benefit that M provides. Suppose, as a result, each seller sets a price \$0.25 higher compared to the case in which M is not present. M's net revenue is \$0.05 per unit.

Now consider the impact of M on welfare. M creates \$0.30 of surplus from intermediation, but each buyer incurs a cost of \$0.15 to join and M incurs a cost of \$0.20 to provide the benefit to each buyer. So M destroys \$0.05 of welfare for each unit sold. Meanwhile, M makes a profit of \$0.05 for each unit sold. Each buyer pays \$0.25 more and gets \$0.30 more in benefits, but each buyer incurs a joining cost of \$0.15, yielding a net reduction in consumer surplus of \$0.10 for each unit sold.

The source of the inefficiency is buyers joining M when, considering all costs, they should not. Specifically, buyers ignore the cost of M's service. This cost is embodied in the higher price of goods offered by sellers, but the seller's price is the same whether buyers purchase directly or through M, so buyers do not face this price signal. This logic holds quite generally. By raising the price of the direct transaction, the intermediary can cause both buyers and sellers to join its service even though jointly they are worse off by doing so. Price coherence causes each side to value the benefit that buyers receive when joining the service: Buyers see this benefit and are enticed to join the intermediary's service, while sellers consider the benefit (and buyers' willingness to pay for it) when evaluating how much they are willing to pay to join the intermediary's service. This is a coordination failure: An individual buyer cannot influence whether sellers join the intermediary and therefore set the higher price. Because the buyer's benefits are counted by both sides, it can be profitable to attract buyers and sellers to the intermediary's service even though the service lowers social welfare.[1] The result illustrates the possibility of "excessive," indeed "adverse" intermediation. (Hence the title of our paper.) The double-counting of the buyer's benefits can also lead to other distortions, such as over-investment in the benefits that intermediaries provide to buyers.

Our numerical example reflects significant simplifications, including homogeneous buyers, a monopolist intermediary, and full information. In the benchmark model in Section 3, we introduce buyer heterogeneity (intermediaries face downward sloping demand for their services), endogenize buyer-side benefits (allowing for over-investment in buyer-side benefits), and explicitly model seller competition (to pin down how much intermediaries can charge sellers). In subsequent sections, we extend the model to allow for competing intermediaries and for intermediaries with superior information.

An intermediary's imposition of price coherence is robust to typical disruptions. In principle, a seller could attempt to dissuade its buyers from signing up with the intermediary in the first place. Then, if these buyers purchase directly, the seller could offer a lower net price than the buyers would receive if purchasing from sellers using the intermediary. Some large sellers manage to implement this strategy, but in general sellers struggle to implement this approach due to market rigidities and the sequence of decision-making, as we discuss in Section 2. One might also imagine a new intermediary offering lower fees to sellers and lower benefits to buyers. But price coherence requires that the gross price to buyers be identical, encouraging buyers to choose the intermediary with the *largest* benefits since associated costs are not borne by buyers. In Section 5, we analyze the case of competing intermediaries, showing that competition among intermediaries intensifies the distortions sketched above. We also demonstrate that competition among intermediaries can create these effects even if buyer joining costs are trivial.

[1] In this simple example, if a buyer's joining cost were smaller than the net value created by M, price coherence would no longer destroy social welfare, though it would still transfer value from buyers to M.

1.1 Related Literature

A well-developed literature explores the microstructure of exchange between buyers and sellers, and develops the role of intermediaries (e.g. marketmakers or traders) in purchasing products from sellers and reselling them to buyers. Important contributions include Gehrig (1993), Spulber (1996), Rust and Hall (2009), and Antras and Costinot (2011). These papers consider contexts in which intermediaries set prices to buyers, but we consider settings where sellers set product prices—yielding importantly different results.

Closer to our work is the burgeoning literature on multi-sided platforms, pioneered by Caillaud and Jullien (2003), Rochet and Tirole (2003), Parker and Alstyne (2005), and Armstrong (2006). Our work differs from most existing multi-sided platform models in our approach to the interactions between the two groups (i.e. buyers and sellers). The standard approach assumes some given interaction benefits (usually linear), with no payment between the groups. Price coherence cannot be studied in that setting for lack of a price set between the groups. In contrast, we model the micro structure of the interactions between buyers and sellers by modeling price-setting sellers that compete to offer a product to buyers. Hagiu (2009) and Belleflamme and Peitz (2010) are among the few papers modeling the micro-structure of buyer and seller interactions in multi-sided platforms, but they do not allow buyers to bypass the platform and purchase directly from sellers. We extend the literature on multi-sided platforms by allowing for the possibility of direct purchases, which is critical for any analysis of price coherence.

The closest framework to the current paper is provided in the literature modeling payment card systems, in which buyers can purchase from sellers using a payment card or cash. Like the literature on payment cards, we consider the efficiency of fee structures that emerge under price coherence (i.e. that there is no surcharge for payment by card) and merchant internalization (i.e. that sellers take into account the buyers' benefit from using the intermediary when evaluating how much they are willing to pay to join the intermediary). Articles in the payment literature that share these features include Rochet and Tirole (2002), Wright (2004), Farrell (2006), Guthrie and Wright (2007), Rochet and Tirole (2011) and Wright (2012). Unlike these papers, we focus on the welfare effects of price coherence. Like Wright (2012) and Bedre-Defolie and Calvano (2013), our results indicate a systematic bias in the fee structure towards card users resulting in the excessive use of payment cards.

Separately, a small literature examines the use of commissions and kickbacks by intermediaries, most prominently Inderst and Ottaviani (2012). We assume that all buyers are perfectly informed, eliminating concerns about an intermediary inappropriately steering buyers to less suitable sellers as in some of the commissions and kickbacks literature. Rather, our concern is that buyers are steered to use the intermediary rather than purchasing directly. This does not arise in Inderst and Ottaviani because they do not allow buyers to purchase directly from sellers. One could consider extending the Inderst and Ottaviani model to allow direct purchases and to allow the intermediary to impose price coherence. To that end, in Section 6 we explore what happens when buyers rely on the intermediary for information about which seller is the best match. We show that price coherence (and indeed the intermediary's existence) still lower consumer surplus and sometimes welfare.

Throughout our analysis, we assume buyers are fully rational. A recent literature considers intermediation under consumer naiveté, in which consumers find it difficult to evaluate the complex products on offer (Inderst and Ottaviani, 2012) or misperceive some product attributes (Murooka, 2013). Relaxing our assumption of full buyer rationality, our model could be extended to allow buyers to find intermediaries' benefits, rebates, or fees more salient than equal changes in sellers' base price, but this extension is beyond the scope of our paper.

Since price coherence constrains firms' actions vis-a-vis other firms in the production and distribution process (such as distributors and payment processors), price coherence is properly viewed as a vertical restraint. Like other vertical restraints such as retail price maintenance, price coherence can suppress price competition by ensuring buyers face the same retail price from sellers regardless of which intermediary they buy through. We extend the literature on vertical restraints (Rey and Vergé, 2008) by identifying two additional harms from the practices we examine: First, price coherence causes over-consumption of intermediaries' services. Second, price coherence spurs over-investment in buyer-side benefits which results in intermediaries incurring excessive costs which are ultimately passed to buyers as higher retail prices.

We proceed as follows. In Section 2, we explore selected markets with price coherence. In Section 3, we provide a formal model of the structure of affected markets. Section 4 analyzes the model for a monopolist intermediary. Section 5 extends the analysis to the case with competing intermediaries, while Section 6 extends the analysis to the case of an intermediary that has an informational advantage in matching buyers and sellers. In Section 7, we discuss possible policy prescriptions.

2 Markets with price coherence

We now turn to six specific markets with price coherence. For each, we begin with the market function and structure. We then turn to the source of the price coherence constraint, whether imposed by intermediaries (explicitly or implicitly), governments (law or regulation), or otherwise.

In the online appendix, we extend selected examples with further details including how regulators, sellers, and alternative intermediaries have attempted to change the market structure. The online appendix also presents three additional markets with price coherence (real estate buyers' agents as well as restaurant reservations and ordering) and provides references for the factual claims made in this section.

2.1 Travel booking networks

Global distribution systems (GDSs) connect airline reservation systems to travel agents (TAs). With hundreds of airlines and thousands of TAs, it would be burdensome to connect each airline to each TA. Instead, a few large GDSs (currently three) broker the connections. The resulting structure typically has four parties: airlines sell through GDSs to reach TAs which serve travelers. In the three-party framework of our model, TAs represent the agents which let buyers (travelers) access the intermediary (GDS).

To date, TA multihoming costs are high, and each TA is effectively limited to a single GDS. Changing to a new GDS requires new training and processes for TA staff. Connecting to multiple GDSs requires systems that are not widely available to combine their results.

Historically, major airlines typically sought to be distributed via all GDSs. In order to reach business travelers who tend to buy the most expensive tickets, airlines need to connect to the GDSs used by the TAs chosen by those business travelers. Because each TA uses only a single GDS, an airline needs to appear in all GDSs if it wants all TAs to be able to sell its flights.

Save for switching costs, GDSs are largely interchangeable to TAs, so a TA typically chooses whichever GDS provides the most valuable incentive payments. Historically, GDSs provided TAs with computer terminals and telecommunications links without charge—a major benefit when IT costs were high. Today, GDS provide payments to TAs, typically including both an up-front payment upon joining the GDS as well as a payment for each flight segment sold. As of 2002, GDS incentive payments to TAs were typically \$1 to \$1.70 per flight segment.

GDSs fund payments to TAs by charging fees to airlines. As of 2002, GDSs charged 3.3% of revenue, an average of $11 per ticket, for travel on United Airlines.

Changing regulations shape airlines' dealings with GDSs. Through 2003, if an airline owned a GDS, it was required to submit its fares and schedules to all GDSs. But by the end of 2002, all airlines had sold their interests in GDSs. Many airlines began to offer their lowest prices as "web fares" available only on their own web sites—to the dismay of TAs who sought to sell all fares. In subsequent negotiations, GDSs obtained "full content access to all of an airline's fares in exchange for sharply lowering their fees to airlines. This contractual commitment restored price coherence—meaning that the base price of a ticket is the same whether the ticket is purchased directly from an airline versus from a TA. (Most TAs, like most airlines, now charge additional fees for tickets booked by phone.)

As airlines' GDS contracts came up for renewal, GDSs sought to raise the fees. By 2012, GDS fees met or exceeded prior levels. GDS payments to TAs have increased in parallel.

Booking networks for hotel rooms and car rentals use a broadly similar structure. See the online appendix.

2.2 Credit and debit cards

Credit and debit cards facilitate all manner of purchases by both consumers and businesses. Prager *et al.* (2009) and Rysman and Wright (2012) present relevant institutions, incentives, and implications.

In general, gross prices are identical whether a buyer pays by credit card, debit card, or in some other way. In some jurisdictions, including ten U.S. states, laws disallow credit card surcharges. Visa and Mastercard used contracts to impose similar rules. That said, litigation and regulation have ended this restriction in some countries. For example, U.S. litigation required Visa and Mastercard to allow merchants to impose credit surcharges if they so choose, beginning in January 2013 (except where prohibited by state law). Worldwide, cash discounts have always been permitted. Though cash discounts and credit card surcharges are similar in their purpose, their effectiveness appears to differ significantly, and cash discounts are seldom used.

To attract consumers to join a given payment card and to shift spending to that card, payment card issuers offer significant and growing benefits to consumers. Early credit cards offered delayed payment and various consumer protections, but no rebates. In 1986, Discover began to offer a 1% rebate card, and multiple Visa issuers added a similar benefit in 1994. Greater rebates became available later, now including multiple U.S. cards with comprehensive 2% rebates. Though the rebates flow through the multi-party card network structure, merchants' payments are the ultimate source of the rebated funds.

Critics allege that this fee structure, with merchants paying high fees and cardholders rewarded for use, promotes over-use of credit cards (as well as some debit cards).

2.3 Insurance brokers and financial advisors

Insurance brokers direct insurance buyers to various insurance sellers, typically obtaining customer and risk characteristics from a buyer and providing quotes for multiple insurers. Financial advisors similarly direct investors among various competing products. Brokers and advisors suffer the incentive problems examined in Inderst and Ottaviani (2012), including commissions that skew their decision to favor particular insurers or products. For example, Canadian insurance regulators reported in 2009 that life insurance brokers are paid approximately $7.2 billion of commissions per year, in addition to widespread perks such as resort vacations. For some forms of insurance, intermediaries' fees can be particularly large: In a 2007 inquiry, the U.S. Government Accountability Office found that just 5% of title insurance premiums were spent on covering losses, while 70% was paid to or retailed by the intermediaries who issue title insurance.

Prices are largely identical for buyers who approach insurers or financial providers directly versus via a broker or other intermediary. For example, the Monetary Authority of Singapore recently noted that life insurance sellers offer the same prices regardless of the distribution channel that a consumer chooses. If an insurer offered lower prices than its brokers, brokers would refer their customers elsewhere.

The resulting market structure causes and preserves brokers' fees. One life insurer told Globe and Mail investigative reporters that it "want[s] to discontinue [] incentives" to brokers but cannot do so because "brokers won't give you policies" without the payments. A Washington state investigation of title insurance called the market structure "reverse competition" because competition between insurers drives commissions up rather than driving prices down. The U.K. Financial Services Authority found a "perception" of advisors and brokers pushing life insurance sales and financial services purchases towards the firms that pay the largest commissions. The Monetary Authority of Singapore points out that this fee structure offers no savings to self-directed customers who prefer to buy life insurance and financial services from a low-cost distribution channel to avoid the commission expense.

Since 2012, Australia and the United Kingdom banned or capped most commissions to life insurance brokers and financial advisors, requiring instead that consumers pay for advice separately from insurance and financial services. Separating payments in this way implies an end to price coherence:

Brokers and advisors attract buyers by competing in part on price. Separately, Singapore required that certain "basic" life insurance be available through a direct channel at a "factory-gate price" plus a nominal administrative fee, bypassing brokers and advisors.

2.4 Marketplaces

Online marketplaces assemble goods from myriad sellers—for example, more than 2 million independent sellers offering products at Amazon Marketplace. Malls perform a similar function in the offline context.

Both online and offline, marketplace operators risk buyers approaching sellers directly, bypassing the marketplace. Online marketplaces compete with purchases from a seller's own site. Malls compete with purchases from a seller's non-mall locations. Powerful marketplace operators sometimes seek a commitment, embodied in contract, that prices through the marketplace be no higher than prices offered elsewhere. For example, Amazon's "general pricing rule" requires that "the item price and total price of an item [a seller] list[s] on Amazon.com [must be] at or below the item price and total price ... via any other online sales channel." Few malls or retailers have reason to make their lease provisions public, but we understand that similar provisions are not uncommon in the context of malls seeking low prices from their merchant tenants. These contractual restrictions attempt to enforce price coherence at the respective marketplaces.

Marketplaces compete to attract buyers by offering a variety of benefits to buyers. For example, Amazon offers superior service, easy returns, and various rebates (such as the rebates discussed in Section 2.5). Mall benefits vary but sometimes include free or low-cost parking, entertainment, gift wrapping (especially at holiday season), and add-on gifts or lotteries (typically requiring a purchase of a certain size from any of the mall's stores). These benefits encourage buyers to purchase in the marketplace rather than directly from sellers.

2.5 Cashback/rebate services

Online "cashback" rebate services offer users discounts when purchasing from participating e-retailers. A registered user clicks from a rebate service site to a merchant's site, makes a purchase from the merchant, and earns a rebate, often 5% to 10% paid after 30 to 90 days. Initially known only to the savviest shoppers, rebate sites have become mainstream: Alexa ranks Ebates the 741^{st} most popular site in the US. From a consumer's perspective, these rebates appear to be a windfall.

Multiple factors assure equal prices for rebate service users. First, as the next section notes, sites largely lack the ability to present different prices to users coming from different sources. In addition, users would view differing prices as improper. Indeed, users occasionally complain about higher prices when referred by a rebate service, although these reports have turned out to be glitches rather than systematic differences. Finally, rebate sites would not allow prices to differ: The CEO of a leading rebate service told one of the authors that he would ban a merchant that increases prices for rebate service users.

Rebate services also include an important element of price discrimination. The buyers who favor rebate services are unusually price-sensitive. A merchant with heterogeneous buyers would find it profitable to set prices that vary according to buyer elasticity—differing posted prices or, if that is infeasible, differing rebates. Such price discrimination is outside the scope of the model considered in this paper, although it would be an interesting direction for future research.

Rebate services also differ from the other examples we examine in that they provide buyers with *money* rather than some other good or service. Ordinarily, intermediary benefits can create gains from trade—benefits worth more to buyers than the intermediary's cost of providing the benefits. In contrast, no gain from trade occurs when an intermediary provides money. Nonetheless, Section 4.5 shows how our model can be extended to fit the case of pure rebates.

2.6 Search engine advertising

Search engine advertising entails large costs to merchants—collectively, some $40+ billion of pay-per-click advertising in 2013. Multiple factors constrain prices to be equal whether or not a user clicks a search advertisement to reach a merchant. In the short run, merchant sites lack a feature to present different prices depending on whether a user clicked an ad. Moreover, search engines might disfavor merchants that use such a strategy were it to become a realistic possibility.

With advertising costs shielded from consumers, search engines compete to attract users. Specifically, search engines offer users numerous online services. Most closely bundled with search advertisements are algorithmic search results (the "left-side" search results for which search engines are best known) which examine billions of pages at no charge to users. Search engines also offer email, image search, videos, maps, and scores of other services, all without charge to users. Furthermore, search engines pay computer, tablet, and phone makers to make their search engines the defaults (offsetting a portion of the cost of making those devices) and pay software developers to install search toolbars that direct users to the corresponding search sites (funding software that is often provided to users without charge). From 2008 to 2010, Microsoft Bing Cashback even paid users who ran searches, clicked ads, and made purchases—rebating a portion of advertisers' fees back to users. These efforts to attract users all result from the market structure created by price coherence.

Price coherence also shapes search engine market shares. Advertisers' posted prices are equal no matter what search engine a user chooses, so users have no incentive to choose the search engine with lowest fees to advertisers. If users paid the advertising costs resulting from their respective clicks, they would notice that Google charges the highest advertising fees, and price-sensitive users would favor other search engines or avoid using search engines to find online merchants. Instead, prevailing market structure invites users to choose the search engine that offers them the most and best "free" services.

3 Model

In this section, we introduce a simple model to capture the effects of price coherence. Initially, we consider the case of a single (monopoly) intermediary, M. (Section 5 analyzes the case of competing intermediaries.) There is a continuum (measure one) of buyers. There are two symmetric but differentiated sellers, and each buyer wants to buy one unit of a product from one of the sellers. A buyer can buy the product directly or through M.

We consider intermediaries that provide benefits to buyers, such as offering complementary products or reducing transaction costs. If M invests $k \geq 0$ per transaction, it can provide a benefit to buyers valued at $b(k)$ per transaction. We assume $b(k)$ is twice continuously differentiable with $b'(k) \geq 0$ and $b''(k) < 0$. Define $\pi(k) \equiv b(k) - k$. We assume $\pi'(0) > 0$. We assume there exists some high enough investment $\overline{k} > 0$ such that $\pi(\overline{k}) = 0$ and $\pi'(\overline{k}) < 0$. Define k^m that maximizes $\pi(k)$, which clearly exists and is unique given our assumptions, and is defined by $\pi'(k^m) = 0$. Note that $0 < k^m < \overline{k}$. Define $\pi^m \equiv \pi(k^m)$, which is M's monopoly profit if all buyers use M and are charged directly for the benefit they obtain from doing so. Our assumptions imply $\pi^m > 0$.

From an individual buyer's perspective, the participation costs of joining M may be significant. These may include costs such as filling out forms, finding and contacting the intermediary, evaluating an intermediary's offer, and learning to use the intermediary's service. We therefore suppose each buyer draws a participation cost c from the distribution G over $[0, \overline{c}]$ with corresponding density g. Over this interval, we assume G is strictly increasing, twice continuously differentiable, and log-concave. We assume $\overline{c} > b(\overline{k})$. This ensures that not all buyers join the intermediary in equilibrium, even if it imposes price coherence and invests in buyer-side benefits until there is no *net* benefit. On the other hand, some buyers have arbitrarily small costs of joining, which ensures that M always operates, even if it cannot impose price coherence. Note that c is a sunk cost. After a buyer incurs c, it does not distort the buyer's decision to use M versus purchase directly. The cost c provides a convenient way to capture the idea that, while buyers obtain surplus from M, some of the surplus may be dissipated. In our model, surplus dissipates not only from the cost of c but also from M's possible over-investment in benefits required to attract buyers due to the cost c. We denote the expected value of c over its full support as $E[c]$.

We assume sellers have no direct benefits from using M. Instead, by joining M, a seller receives the benefit that M delivers to the seller's buyers. That is, a seller's (indirect) benefits are derived endogenously. We also assume sellers do not incur participation costs when signing up for M's service. This reflects that such costs are normally a small part of the overall costs and revenues a seller considers when joining M.

We assume a standard Hotelling model of seller competition, so that a buyer's ideal value of the characteristic x is drawn from a uniform distribution on the unit interval $[0, 1]$. The two sellers are assumed to be located at the ends of the unit interval. To purchase from a seller that is a distance y away from the buyer's ideal location in characteristic space, the buyer faces disutility ty, so the buyer obtains utility $v - ty$ from buying one unit from the seller. Sellers have a cost d per unit sold. To keep buyers ex-ante homogenous, we assume each buyer only observes its value of x after deciding whether to join M. To ensure that no seller wants to set a price that results in it serving every buyer of a given type (i.e. serving all buyers that purchase directly or all buyers that purchase through an intermediary), we assume product differentiation is sufficiently strong.[2] To ensure that buyers always prefer to buy from one of the sellers, possibly directly, rather than not buy at all, we assume that v is sufficiently high.[3]

Since our model features unit demand and symmetric sellers, M cannot do better than charge a linear (per-transaction) fee to sellers. We denote this fee as p_S. We assume M charges buyers a linear fee, which we denote as p_B. In general, we require $p_B \geq 0$, but in Sections 4.3 and 4.5 we consider an intermediary that can costlessly transfer funds to the buyer.

With price coherence, M finds it optimal to also charge a fixed participation fee to each buyer. As we discuss in Section 4.4, fixed participation fees provide a way for M to capture some of the surplus

[2] A sufficient condition is $t > b(\overline{k})$.
[3] A sufficient condition is $v > d + 2t + b(\overline{k})$.

it would otherwise leave with buyers, thereby strengthening the negative effect of price coherence on buyers.[4] Because fixed participation fees are seldom used in practice, we primarily focus on the case without these fees.

The timing is:

1. M determines its investment in buyer-side benefits k, the fees p_B and p_S it charges to buyers and sellers per transaction, and whether to impose price coherence (whether sellers must charge the same price for buyers that come through M versus buyers that purchase directly).
2. Each buyer observes its value of c and decides whether to join M. If a buyer joins M, the buyer incurs the cost c. Each seller decides whether to join M and what price(s) to set to buyers.
3. Each buyer observes its value of x and decides which seller to purchase from (if any). If the buyer purchases, and if both the buyer and its chosen seller have joined M, the buyer decides whether to purchase through M. All benefits, costs and transfers between parties are realized.[5]

Our equilibrium concept for this full information setting is subgame perfect equilibrium. Given the fixed joining cost buyers face (and in the absence of a fixed payment to buyers), there are multiple equilibria in the continuation game following any given fees and investment level set by M. For instance, there always exists a trivial equilibrium in the continuation game in which M does not attract any buyers or sellers because buyers do not expect any sellers to join and vice versa. To select among equilibria in the continuation game, we assume that if there are equilibria in which M can profitably attract one or both sellers to join, then one of these is selected. This captures the idea that M should be able to overcome the trivial equilibrium if it is profitable to do so.

4 Monopoly intermediary

In this section, we analyze the model introduced in Section 3. We first consider a case in which M cannot impose price coherence (Section 4.1). We then consider the impact of imposing price coherence (Section 4.2) and some simple extensions (Sections 4.3 to 4.5).

[4]We also assume that it is not possible to charge negative participation fees (i.e. a payment for a buyer to join M). Only limited *fixed* subsidies are likely to be feasible in practice due to the adverse selection problem that otherwise would emerge (attracting buyers that join solely to collect the subsidy). Moreover, as we show when participation fees are allowed, M ordinarily wants to set a positive participation fee.

[5]Specifically, the benefits v, mismatch costs and the price paid from buyer to seller are realized for completed purchases. In addition, the benefits $b(k)$, costs k, and fees p_B and p_S are realized on purchases through M.

4.1 Intermediation without price coherence

Consider a setting in which M cannot impose price coherence. We will show that M chooses the efficient investment level k^m that maximizes the net benefit to buyers $b(k) - k$. At k^m, the marginal benefit to buyers of one extra dollar of investment exactly equals one dollar. As a monopolist, M can then set its fee (either to buyers directly, or equivalently, through sellers) in the usual monopoly way to trade-off a higher margin per transaction with a reduced number of transactions as fewer buyers join. The resulting fee charged to sellers (or equivalently buyers), p_S^*, follows the standard monopoly pricing formula

$$p_S^* = k^m + \frac{G\left(b(k^m) - p_S^*\right)}{g\left(b(k^m) - p_S^*\right)}. \tag{1}$$

Proposition 1 formalizes these results.

Proposition 1 *Suppose M cannot impose price coherence. There exists an equilibrium in which M invests $k = k^m$ in benefits to buyers and sets the fees $p_B = 0$ and $p_S = p_S^*$, where p_S^* is the solution to (1) and satisfies $k^m < p_S^* < b(k^m)$. Sellers both join M and set the equilibrium price $d + t$ for buyers that purchase directly and the price $d + t + p_S^*$ for buyers that purchase through M. Buyers join if and only if they draw $c \leq b(k^m) - p_S^*$ and such buyers always purchase through M.*

The appendix provides the proof of this result and all others.

The equilibrium in Proposition 1 entails sellers passing through to their buyers any fee they are charged by M, so M does just as well by charging buyers directly. The equilibrium in Proposition 1 is equivalent to other equilibria with $p_B \geq 0$ and $p_S \geq 0$ such that $p_B + p_S = p_S^*$, in that all such equilibria yield identical decisions by buyers and sellers, as well as identical amounts paid or received by each agent. This equivalence is consistent with the more general neutrality result of Gans and King (2003). As noted in the proof of Proposition 1, the equilibrium outcome in Proposition 1 is actually unique subject to the indeterminacy of the fee structure between buyers and sellers, and the resulting indeterminacy of seller prices.

4.2 Impact of price coherence

Imposing price coherence allows M to increase its profits compared to the case without price coherence. Under price coherence, buyers pay the same price whether they buy through M or directly. Thus, a buyer is willing to join M provided the benefits the buyer obtains, $b(k) - p_B$, exceed the buyer's joining cost c. As a result, $G(b(k) - p_B)$ buyers join. Having joined, buyers get the additional surplus

$b(k) - p_B$ if they buy through M compared to buying directly. Therefore, sellers are willing to pay up to $b(k) - p_B$ per transaction facilitated by M since they can offer this surplus to their buyers.[6] (If sellers were charged more than $b(k) - p_B$, each seller would prefer to reject M's service and sell only directly to buyers.) We will show that M maximizes its profit by setting no fee to buyers, which yields M profit of $(b(k) - k)\, G(b(k))$. M's maximization problem is as follows:

$$k^* = \arg\max_k \left(b\left(k\right) - k\right) G\left(b\left(k\right)\right). \tag{2}$$

M invests in buyer-side benefits beyond the efficient level k^m so as to expand demand $G\left(b(k)\right)$. The following proposition formalizes these results[7]:

Proposition 2 *Suppose price coherence holds. There exists an equilibrium in which M invests k^* satisfying $k^m < k^* < \overline{k}$ in creating benefits for buyers and sets the fees $p_B = 0$ and $p_S = b(k^*)$. Sellers both join the intermediary and set the equilibrium price $d + t + G\left(b(k^*)\right) b(k^*)$ that applies for all buyers. Buyers join if and only if they draw $c \leq b(k^*)$ and such buyers always purchase through M.*

It is instructive to compare the constraints that limit M's fees in Propositions 1 and 2. Without price coherence, buyers know when joining M that sellers always join and that sellers pass through any fees from M. Buyers therefore only join M if the benefits exceed the higher prices and the cost of joining. This limits the fees M wants to charge: If M sets fees too high, then too few buyers will join. However, with price coherence, buyers know there is no price difference between buying through M versus buying directly. Buyers therefore join if the benefit they receive from M exceeds their cost of joining. In this case, buyers' choices do not directly constrain how much M can charge. Instead, M's fees are constrained by sellers' willingness to pay to join. In particular, sellers do not join if M charges more than $b(k)$ because with such a high fee, M provides the seller's buyers with less value than what the seller has to pay to offer M's benefit to its buyers and they would be better off rejecting M's service and selling directly to buyers at a lower price.

We now compare the outcomes with and without price coherence.

Proposition 3 *Comparing the equilibria characterized in Proposition 1 and 2, M always imposes price coherence if permitted to do so. M chooses the efficient investment in buyer-side benefits without*

[6]This condition corresponds to the merchant internalization result in the payments card literature. For example, see Wright (2012).

[7]As we will show in the proof of the proposition, the equilibrium characterized in the proposition is unique, other than the trivial equilibrium in which no buyers and sellers join, which is ruled out by our equilibrium selection criterion.

price coherence, but over-invests in creating these benefits with price coherence. Additionally, too few buyers join M without price coherence, and too many buyers join M with price coherence. Moreover, the consumer surplus generated by M is positive without price coherence but negative with price coherence.

As Proposition 3 indicates, M always wants to impose price coherence. With price coherence, M obtains $\max_k (b(k) - k) G(b(k))$ rather than the lower amount $\max_{p_S \geq 0} (p_S - k) G(b(k) - p_S)$ that arises without price coherence. The comparison in profit expressions highlights that M's demand curve shifts up under price coherence, allowing M to charge higher fees to sellers and at the same time attract more buyers. Indeed, in a setting without price coherence, if M tried to set the same high fee to sellers that it sets under price coherence, it would obtain no demand.

Proposition 3 reveals that buyers are worse off in aggregate under price coherence compared to the case in which M does not exist. This loss results from the higher prices that sellers charge under price coherence. Compared to the case without M, prices end up higher by $G(b(k^*)) b(k^*)$, which represents a loss in surplus for all buyers. On the other hand, $G(b(k^*))$ buyers purchase through M and get the benefit $b(k^*)$. These two effects exactly cancel out, and the net effect of M on buyers is that buyers incur an additional cost of joining that equals $\int_0^{b(k^*)} c dG(c)$. If buyers could coordinate, they would be jointly better off not joining M. Without such coordination, buyers rationally join M's service even when it lowers buyers' joint surplus. Without price coherence, M creates a positive surplus for consumers, so buyers are also strictly worse off under price coherence compared to the case without price coherence. While intermediation makes buyers worse off in aggregate, there are distributional effects. Among those joining M, some are better off (those with $c < G(b(k^*)) b(k^*)$) and some are worse off (those with higher c). On the other hand, all the buyers not joining M are worse off—they obtain no benefit from intermediation despite facing increased prices.

By imposing price coherence, the intermediary can cause buyers to count the benefit $b(k)$ from intermediation even though sellers also count it in the fee they pay M (and so in the prices they set to buyers). The double-counting of buyer benefits explains why it can be profitable to attract buyers and sellers to M when M lowers buyers' and sellers' total surplus, and even when M lowers total welfare.

An efficient outcome would entail M choosing the efficient level of investment k^m and buyers facing a fee of k^m to use M's service, so that buyers would face the true cost of the service they consume. This would ensure that the marginal buyer contributes exactly zero to welfare, and welfare would match the first-best solution. Compared to this ideal, both the case without price coherence and the case with price coherence involve distortions.

Without price coherence, while M invests efficiently in buyer-side benefits, buyers end up paying the monopoly fee p_S^* to use M's services, which is more than k^m. As a result, all buyers (even the marginal buyer) make a positive contribution to welfare. As a result of M's market power, too few buyers join M compared to the efficient level.

In comparison, with price coherence in place, buyers ignore the cost of providing M's service. This cost is covered by the higher price of goods offered by sellers, but the seller's price is the same whether a buyer purchases directly or through M, so buyers do not face this price signal. As a result, too many buyers join. Moreover, because buyers do not face any price signal for using M, demand for M is strictly increasing in k, which results in M investing excessively in buyer-side benefits. Both of these effects result in too many buyers completing their purchases through M compared to the first-best level, with some inframarginal buyers joining M and making a negative contribution to welfare.

The effect of price coherence (or the existence of M) on total welfare is therefore ambiguous in this monopoly setting. Explicit conclusions on total welfare are possible with stronger assumptions.

Proposition 4 *The intermediary's contribution to welfare is positive without price coherence. Suppose $G(c)$ is the power function $G(c) = \left(\frac{c}{\bar{c}}\right)^{\alpha}$, where $\alpha > 0$. Then M's contribution to welfare under price coherence is negative if and only if $\frac{b(k^*)-k^*}{k^*} < \alpha$. In this case, eliminating price coherence (or M) would increase welfare.*

Proposition 4 shows that the intermediary destroys welfare under price coherence if the buyer-side benefits created by M are insufficiently valuable relative to M's cost in providing these benefits. For example, if demand is linear (i.e. $\alpha = 1$), the intermediary destroys welfare if and only if the rate of return on investment is less than 100%. If demand is convex, an even greater return on investment would be required to avoid M destroying welfare. This result suggests that an intermediary is especially likely to reduce welfare if it creates limited net value in the first place and if buyer demand is not sufficiently concave.

4.3 Rebates to buyers

The preceding results do not allow M to set (costless) rebates to buyers. Without price coherence, such rebates are redundant, as sellers would immediately pass the cost of any rebate back to buyers via higher prices. Under price coherence, such costless rebates provide a more efficient way for M to attract buyers to join. With rebates, M could retain the efficient level of buyer-side benefits $b(k^m)$, and use rebates to attract additional buyers to participate. What buyers enjoy in terms of buyer-side benefits and rebates, they end up paying in higher gross prices. Since buyers still incur a joining cost, all buyers are again worse off due to price coherence (or the existence of M). In this case, the results of Propositions 3 and 4 still hold but without the additional over-investment in buyer-side benefits.

Corollary 1 *Suppose M can set a costless rebate ($p_B < 0$). Then Propositions 3 and 4 continue to apply except that M no longer over-invests in creating buyer-side benefits under price coherence (i.e. k^* is replaced by k^m).*

4.4 Fixed participation fees

Without price coherence, M does not benefit from charging a fixed fee to buyers. Such a fee has the same effect as charging a per-transaction fee p_B to buyers or a per-transaction fee p_S to sellers, which only affects how many buyers will join and use M but not whether sellers will join.

Under price coherence, a fixed participation is not equivalent to the per-transaction fee p_B. Recall that sellers are willing to pay M up to $b(k) - p_B$ per transaction facilitated by M. However, a fixed participation fee is a sunk cost at the point when buyers decide whether to buy from one seller or another, and a fixed participation fee therefore does not directly affect how much sellers are willing to pay M under price coherence.[8] Thus, a fixed participation fee provides a way for M to extract some of the positive surplus enjoyed by its inframarginal buyers.

Denote the fixed participation fee F. Then M collects F in addition to $b(k) - k$ on each buyer that joins, so its profit is $(F + b(k) - k)G(b(k) - F)$. M double-counts buyer-side benefits—once in the fees it can charge sellers and once from the fixed fee it can charge buyers. As a result, M invests until \$1 of extra investment generates just \$0.50 in buyer-side benefits. Formally, M chooses k^F to satisfy

$$b'(k^F) = \frac{1}{2}. \tag{3}$$

Given the investment level k^F, M sets a fixed fee F^* to solve the standard monopoly pricing problem where the fee collected from the seller on each transaction ($b(k^F)$) acts to reduce M's perceived marginal cost. Thus,

$$F^* = \left(k^F - b(k^F)\right) + \frac{G\left(b(k^F) - F^*\right)}{g\left(b(k^F) - F^*\right)}. \tag{4}$$

[8] The fee is set in stage one and collected in stage two from the buyers that choose to join M.

Then we can show the following results:[9]

Corollary 2 *Suppose M can set a fixed participation fee to buyers. It will invest k^F to satisfy (3) and set the fixed fee F^* to satisfy (4). Proposition 3 holds subject to an additional condition to establish that too many buyers join M with price coherence.*[10] *Proposition 4 is amended: M's contribution to welfare under price coherence is negative if and only if $\frac{b(k^F)-k^F}{k^F} < \frac{\alpha}{1+\alpha^2}$. In this case, eliminating price coherence (or M) would increase welfare.*

M's effect on consumer surplus includes an additional negative component. The effect of higher prices exactly cancels with buyer-side benefits, as in Proposition 3. Consumer losses then come from two separate sources: First, consumers incur costs to join M, as before. Second, consumers pay the fixed fee F.

The effect of the fixed fee on welfare is ambiguous. On one hand, the fixed fee can result in even more over-investment in buyer-side benefits. On the other hand, the fixed participation fee tends to reduce the number of buyers joining M, which was excessive without a fixed fee. Thus, the addition of fixed fees can broaden or reduce the conditions in which M reduces welfare, compared to the conditions in Proposition 4.

4.5 A pure cashback service

Consider an intermediary that provides buyers with pure financial transfers (i.e. cashback or rebates) but no other benefits. Compared with Section 4.3, the key change in this section is that the intermediary provides *only* cashback and no other benefits, i.e. $b(k) = 0$. This broadly matches the online cashback services presented in Section 2.5. Assume the intermediary still faces a cost per transaction of k.

In our model without a fixed participation fee, such an intermediary cannot profitably operate. Even with price coherence, the most the intermediary can charge sellers is the amount it pays to buyers (i.e. the rebate per transaction). But given the cost of handling each transaction (or any cost of operating), the intermediary loses money. For a pure cashback service to be viable, the intermediary must be able to capture some of the surplus that buyers obtain.

[9] Without a fixed fee, $\overline{k}$ can be taken as the upper bound for k since any higher k will imply M can never recover its costs. When M can also set a fixed fee, its preferred choice of k (i.e. k^F) can exceed $\overline{k}$. To handle this possibility, the conditions in Section 3 that require $\overline{k}$ be not too large become $\overline{c} > b(max(\overline{k}, k^F))$, $t > b(max(\overline{k}, k^F))$, and $v > d+t+b(max(\overline{k}, k^F))$. This ensures that the parameters $\overline{c}$, t and v are still sufficiently large.

[10] A sufficient condition is that $G(c)$ is the power function and either $\alpha \geq 1$ or if $\alpha < 1$ then $\frac{b(k^M)-k^M}{k^M} < \frac{\alpha}{1-\alpha}$.

The ability to set a fixed joining fee can enable an intermediary to collect this revenue. With price coherence, the intermediary can set $p_B = -\bar{c} - \delta$ and $p_S = \bar{c} + \delta$ for some $\delta > k$. The negative value of p_B denotes that it is a transfer to buyers. Sellers are willing to pay $\bar{c} + \delta$ for each purchase coming through M since this is the benefit their buyers enjoy. Since a buyer with joining cost c expects to get $\bar{c} + \delta - c$ more surplus by joining M versus buying directly, all buyers join. M can then charge a fixed participation fee to buyers of at least δ, and still profitably attract all buyers.

In practice, few cashback services charge an up-front fee. Instead, cashback services often rely on selling the rights to third-parties to advertise and cross-sell products to their buyers. Suppose M obtains an expected profit per buyer π_A from selling such rights, such that $k < \pi_A < E[c]$, so the profit from doing so can cover the intermediary's costs per buyer but does not cover the buyers' costs of joining M. We assume that buyers expect no surplus from these added services, so their presence does not affect their decision to join M.

Without price coherence, any charge to sellers is passed back to buyers, so it is not viable for M to charge sellers to fund a rebate to buyers. On the other hand, with price coherence, M can charge sellers up to the benefit buyers enjoy from going through M versus buying directly, i.e. the rebate. If M charges sellers this maximum amount, then M's profit is $\pi_A - k$ per buyer, which is positive given the assumption that $\pi_A > k$. Signing up buyers and sellers is profitable due to the opportunity to cross-sell to these buyers. To make sure all buyers participate, M sets a rebate equal to $\bar{c}$. It then obtains the profit $\pi_A - k$. The welfare generated by M is, however, $\pi_A - E[c]$, which is negative given our assumption that $\pi_A < E[c]$. Likewise, the consumer surplus generated by M is $-E[c]$ given prices are higher by exactly the amount of the rebate. Thus, we have shown:

Corollary 3 *Suppose a cashback intermediary M can sell an add-on service which generates expected profit π_A per buyer, where $k < \pi_A < E[c]$. M only operates if it can impose price coherence. Eliminating price coherence (or M) would increase consumer surplus by $E[c]$ and welfare by $E[c] - \pi_A$.*

Cross-selling may only provide a small net benefit to the cashback intermediary. Yet the intermediary can offer relatively large rebates in order to get buyers to join, in the process lowering consumer surplus and welfare. Intermediation is again excessive in the sense that too many buyers use the intermediary to buy; indeed, on these assumptions, all do but none should.

A pure cashback service could also become viable under price coherence if a portion of buyers value rebates more than they dislike an increase in the seller's price. For example, M's rebate may be more salient to some buyers than any difference between the sellers' prices. Alternatively, consider the case in which some buyers act as agents, making purchases for reimbursement by a principal, with the entire cashback benefit retained by the agent provided the agent pays the seller's standard price. While these contexts yield a similar result—that cashback services can operate profitably—the mechanisms and modeling are quite different. We therefore leave these possibilities for future research.

5 Competing intermediaries

One might hope that the entry of a rival intermediary would help address the distortion in fees that arises when a monopoly intermediary imposes price coherence. Our analysis suggests otherwise.

Consider the incentives of buyers. To attract buyers away from an established intermediary, an entering intermediary needs to offer greater benefits to buyers. This reflects that, facing non-trivial joining costs, buyers tend to join a single intermediary, while sellers are willing to join multiple competing intermediaries to cater to these buyers. As a result, entry tends to push intermediaries to compete to attract buyers, accentuating buyer-side benefits.

In this section, we formally model competition between two identical intermediaries to capture this logic, which we label M^1 and M^2. Each intermediary decides whether to impose price coherence, and sets its fees and investment level k in stage one. Each buyer must incur a cost c to join an intermediary in stage two, where each buyer draws c from G as in Section 3. If a buyer joins both intermediaries, it incurs its c twice, but can only buy through one intermediary when it ultimately makes a purchase. The model is otherwise unchanged.

In this setting, it is natural for sellers to join both intermediaries and for buyers to join only one. This leads to a competitive bottleneck equilibrium similar to that analyzed in Armstrong (2006) and Armstrong and Wright (2007). In the competitive bottleneck equilibrium, intermediaries compete to sign up buyers exclusively. Sellers want to access these buyers, and each intermediary then sets fees to sellers as if the intermediary does not face competition. The need to attract buyers to their respective platform leads to even greater over-investment in buyer benefits, beyond what a monopoly intermediary would choose. This strengthens our previous welfare results.

As in much of the literature on competing multi-sided platforms (e.g. Caillaud and Jullien (2003), Armstrong and Wright (2007), and Ambrus and Argenziano (2009)), there are often multiple equilibria in the continuation game following given fees and investment levels set by the two intermediaries. (For example, facing the same set of fees, all participating buyers and sellers could join one intermediary, or all could join another.) To focus on the competitive bottleneck equilibrium, we assume that whenever there are equilibria in the continuation game in which both sellers join both intermediaries, then one such equilibrium is selected.

We first consider what would happen without price coherence. Without price coherence, competition between intermediaries ensures that each buyer faces the cost k^m of using an intermediary's service, either directly, or through seller's prices, and therefore each buyer joins and uses an intermediary's service only when it is efficient to do so.

Proposition 5 *Suppose each of two competing intermediaries cannot impose price coherence. There exists an equilibrium in which both intermediaries invest $k = k^m$ in benefits to buyers and set the fees $p_B = 0$ and $p_S = k^m$. Sellers join both intermediaries and set the equilibrium price $d + t$ for buyers that purchase directly and the price $d + t + k^m$ for buyers that purchase through M. Buyers with $c \leq \pi^m$ randomize over which intermediary to join and use. Buyers with $c > \pi^m$ do not join either intermediary. If the intermediaries can impose price coherence, the above equilibrium no longer holds. Each intermediary strictly prefers to impose price coherence given that the other does not.*

Proposition 5 establishes that if intermediaries cannot impose price coherence, they invest efficiently in buyer-side benefits (i.e. choosing k^m), and pass the associated costs on to sellers who in turn pass them on to buyers. This leads to the first-best outcome, with buyers rather than the intermediaries retaining the full surplus. However, Proposition 5 also shows that each intermediary prefers to impose price coherence, ruling out the efficient outcome.

Next we show that there is a competitive bottleneck equilibrium in which both intermediaries impose price coherence.

Proposition 6 *Suppose each of two competing intermediaries can impose price coherence. There exists an equilibrium in which both intermediaries adopt price coherence. The intermediaries invest $k = \overline{k}$ and set fees $p_B = 0$ and $p_S = b(\overline{k})$. Note $\overline{k} > k^m$ which implies excessive investment in buyer-side benefits. Buyers with $c \leq b(\overline{k})$ randomize over which intermediary to join and use. Buyers with $c > b(\overline{k})$, do not join either intermediary. Sellers join both intermediaries and set the equilibrium price $p_1 = p_2 = d + t + G(b(\overline{k}))b(\overline{k})$.*

Compared to the case with a single intermediary, competition between rival intermediaries works to further raise their investment in buyer-side benefits in order to attract buyers to their respective platforms. Specifically, in the competitive bottleneck equilibrium, intermediaries continue attracting buyers until the benefit they create per transaction, $b(k)$, equals the cost to them of creating this benefit, k. This equality occurs at the investment level $\overline{k}$.

We can now evaluate the welfare effects of price coherence and intermediation.

Proposition 7 *Comparing the equilibria characterized in Proposition 5 and 6, eliminating price coherence increases consumer surplus and welfare by* $G(\pi^m)\pi^m + \int_{\pi^m}^{b(\overline{k})} cdG(c)$. *Eliminating intermediation increases consumer surplus and welfare by* $\int_0^{b(\overline{k})} cdG(c)$.

Proposition 7 shows that too many buyers join M in the competitive equilibrium. Without price coherence, the first-best number of buyers join (i.e. those with $c \leq \pi^m$). With price coherence, all buyers with $c \leq b(\overline{k})$ join M. Given $b(\overline{k}) > b(k^m) > \pi^m$, far too many buyers join M compared to the first-best outcome. Price coherence harms consumers and welfare, and these results hold even if most buyers have very low values of c. To see this, note that consumer surplus and welfare are lower by $G(\pi^m)\pi^m$ compared to the case without price coherence, even ignoring the additional losses arising from buyers' costs of signing up with an intermediary.

Since intermediaries make no profit in equilibrium, and sellers only make their normal equilibrium profit, an intermediary could do better if it could induce buyers and sellers to join it exclusively. An intermediary might consider the deviation of offering buyers the benefit $b(k^m)$ instead of $b(\overline{k})$ and charging sellers above k^m but less than $b(k^m)$. If the deviating intermediary followed this path and managed to attract buyers and sellers, it would earn a positive profit and would also increase welfare. However, this deviation would only be profitable if buyers and sellers coordinated on the intermediary despite it offering lower buyer-side benefits. Price coherence makes such coordination unlikely. Since prices are the same no matter which intermediary a buyer chooses, each buyer would prefer to join the intermediary offering higher buyer-side benefits (if the buyer expects sellers to also join that intermediary)—although when all buyers do this, gross prices end up increasing and buyers are collectively worse off. This outcome highlights that the market failure results from a coordination failure by buyers, in light of the incentives suppressed by price coherence. Intermediaries need not benefit from this market failure, and this market failure can arise even if intermediaries are highly competitive, as we assumed in this section.

6 Intermediaries with superior information

Suppose a buyer does not know the best seller to buy from. In this section, we consider an intermediary that has superior information (on prices and match quality) and therefore can help each buyer find a suitable seller. This could capture, for instance, an insurance broker (as in Section 2.3) who helps a buyer select a suitable insurance provider.

We modify the benchmark model of Section 3 as follows. We set buyers' transactional benefit $b(k)$ to zero in order to focus on the endogenous benefit buyers can obtain through M's matching service. We continue to denote the cost per transaction through M as k but assume it is exogenously given. M observes price and match information with respect to each seller that joins it, and thus knows which seller is the best match for each buyer among sellers that have signed up. Buyers observe only the fees that M charges. In particular, at the time a buyer chooses a seller, the buyer observes neither sellers' prices nor its own location in characteristic space (and hence its mismatch cost). However, a buyer can obtain information in one of two ways. If a buyer joins M, the buyer obtains M's recommendation. Alternatively, a buyer can obtain full information on both sellers by incurring an unrecoverable search cost s (e.g. using a comparison or review site). We assume $k < s < \bar{c}$ so that M can, in principle, lower the cost of finding out which seller is the best match for a given buyer, although only for some buyers. In stage two, each buyer chooses between joining M or remaining independent (in which case the buyer may pay s to obtain the information, or may elect to proceed without the information). Having chosen a particular seller, the buyer learns the seller's actual price and match, and the buyer then decides whether to complete the purchase with the seller.

The modified timing and information structure is as follows:

1. M determines the fees p_B and p_S it charges to buyers and sellers per transaction, and whether to impose price coherence.
2. Buyers and sellers observe p_B and p_S and decide whether to join M. If a buyer joins M, the buyer incurs the joining cost c. Alternatively, a buyer can choose to obtain price and match information itself, incurring the cost s, or not to obtain the information. Each seller decides what price(s) to set to buyers.
3. If a buyer joins M, the buyer receives a recommendation from M of which seller to buy from. If a buyer obtains information directly, the buyer learns sellers' prices and match values. Otherwise, the buyer receives no additional information. Each buyer chooses a seller to buy from.
4. Having chosen a particular seller, each buyer observes its value of x and that seller's price. The

buyer then decides whether to complete the purchase. If the buyer and seller in question have both joined M, the transaction is completed through M. In this case M incurs the cost k and receives the fees p_B and p_S, if any.

Since any information buyers receive from M is not verifiable, M cannot do better than giving a simple recommendation of which seller to buy from. We show that in equilibrium, each buyer follows M's advice. We continue to assume that M maximizes its profit. However, for a given level of profit, M prefers the allocation that gives its buyers the highest utility.[11] Our equilibrium concept is perfect Bayesian equilibrium. We maintain the same equilibrium selection rule as in Section 3, which avoids trivial equilibria when M can profitably attract one or both sellers to join.

With symmetric prices, buyers reduce their expected mismatch cost from $t/2$ to $t/4$ by incurring the search cost s and obtaining their match information. To ensure that buyers prefer to obtain price and match information themselves rather than randomly selecting a seller, we add the additional constraint that the mismatch cost is sufficiently high (i.e. $t/4 > s$). Finally, we continue to assume that v is high enough that buyers always want to complete their purchases.[12] In all other respects, the setup matches the model introduced in Section 3.

We first show what happens without price coherence. The results parallel those of Section 4.1. Whether M uses a buyer fee or seller fee is again irrelevant, so we can normalize the buyer's fee to zero. We establish a symmetric equilibrium in which buyers with low value of c join M and are matched efficiently through M, while those with high c search and buy directly. Specifically, buyers with $c \leq s - p_S$ join M, but not otherwise. This creates demand $G(s - p_S)$ for M's service, and M sets p_S to maximize $(p_S - k)G(s - p_S)$, resulting in the standard monopoly pricing

$$p_S^* = k + \frac{G\left(s - p_S^*\right)}{g\left(s - p_S^*\right)}, \tag{5}$$

where $k < p_S^* < s$. These results are shown formally in Proposition 8.[13]

Proposition 8 *Suppose M cannot impose price coherence. There exists an equilibrium in which M sets the fees $p_B = 0$ and $p_S = p_S^*$, where p_S^* is the solution to (5). A buyer joins M if and only if it draws $c \leq s - p_S^*$, and such buyers always purchase through M. Each seller sets the equilibrium*

[11] Inderst and Ottaviani (2012) note that intermediaries might care about buyers' utility in light of their reputation, potential liability and ethics. We only require this to be true in a weak tie-breaking sense.

[12] A sufficient condition is $v > d + 2t + \frac{t}{2(1-G(s))}$.

[13] As we show in the proof of the proposition, the equilibrium outcome in the proposition is unique, subject to the indeterminacy of the fee structure between buyers and sellers, and the resulting indeterminacy of seller prices.

price $d+t$ for buyers that purchase directly and $d+t+p_S^*$ for buyers that purchase through M. The intermediary recommends that each buyer buy from the seller that is best for the buyer from among the sellers joined. Buyers that join M always follow its advice.

With price coherence, a symmetric equilibrium again arises in which buyers with low c buy through M while those with high c search and buy directly, with both sellers signing up to M and setting a single price that reflects the weighted average costs of transactions through M and direct transactions. M's fees are limited by sellers' willingness to participate. If M increases its fees too much, a seller's equilibrium price would become too high and a seller would find it profitable to deviate by not joining M, avoiding the fee charged by M, setting a somewhat lower price, and attracting most or all of the buyers that purchase directly. However, such a deviating seller would no longer sell to buyers that come through M as M would steer such buyers to the non-deviating seller by always recommending it to buyers.

We formalize these results in a proposition.[14]

Proposition 9 *Suppose price coherence holds and $t > k + \frac{G(s)}{g(s)}$. Then M charges nothing to buyers to join (i.e. $p_B = 0$). A buyer joins M if and only if it draws $c \leq s$, and such buyers always purchase through M. Both sellers join M. The intermediary recommends that each buyer buy from the seller that is best for the buyer from among the sellers that joined M. Buyers that join M always follow M's advice. Sellers set the equilibrium price $d+t+G(s)p_S$ for all buyers, where $p_S = \frac{2t}{G(s)}\left(\frac{1}{\sqrt{1-G(s)}} - 1\right)$ if $G(s) \leq \frac{3}{4}$, and $p_S = \frac{t}{2G(s)(1-G(s))}$ if $G(s) > \frac{3}{4}$.*

By not charging buyers, M can ensure that more buyers join and thereby reduce the payoff to any seller that deviates and does not join. This allows M to charge more to sellers. The condition on t in Proposition 9 ensures the additional profit from charging sellers more always exceeds the additional revenue obtained from charging buyers directly, so that M's preferred (non-negative) fee to buyers is zero.[15] Note that any other condition that leads M not to charge buyers will ensure Proposition 9 still holds. Without any payment to M, each buyer ignores the cost M incurs in matching buyers to sellers, and each buyer only compares its own cost of joining M versus obtaining price information directly. Either way, M wants to impose price coherence, which reduces buyer surplus. Indeed, as

[14] The equilibrium characterized in the proposition is unique, other than the trivial equilibrium in which no buyers and sellers join, which is ruled out by our equilibrium selection criterion.

[15] In the proof of Proposition 9 we show that this assumption holds if buyer demand for M is linear. Indeed, it suffices for $G(c)$ to be the power function with $\alpha > \frac{1}{3}$.

in the previous settings, buyers would be jointly better off if M did not exist, despite M's role in lowering their costs of obtaining price and match information. Moreover, in the proof of the following proposition, we show that M makes buyers jointly worse off, even ignoring buyers' joining costs.

Proposition 10 *Comparing the equilibria characterized in Proposition 8 and 9, M always imposes price coherence if permitted to do so. Too few buyers join M without price coherence. Too many buyers join M under price coherence. The consumer surplus generated by M is positive without price coherence but negative with price coherence.*

Eliminating M (or price coherence) can raise or lower welfare depending on the cost savings that M provides to buyers, versus the costs M entails in handling the transactions it intermediates. Thus, even though M may raise the overall costs of matching, buyers may continue to use the intermediary, and the intermediary may remain profitable.

Proposition 11 *M's contribution to welfare without price coherence is positive. Suppose that $G(c)$ is the power function $G(c) = \left(\frac{c}{\bar{c}}\right)^{\alpha}$. M's contribution to welfare under price coherence is negative if and only if $k > \frac{s}{1+\alpha}$. In this case, eliminating price coherence (or M) would increase welfare.*

As in prior sections, participants' incentives drive the resulting behavior and outcomes. Specifically, buyers elect to use M to get information because they face no additional cost in doing so, even though this drives increased costs to sellers. This is generally similar to other sections, albeit with M's benefit here comprised of information and a recommendation rather than the tangible or pecuniary $b(k)$ benefit in prior sections. Meanwhile, sellers' motivation is somewhat different. Sellers are willing to pay for transactions through M not because of the benefits that buyers receive, but because M will never recommend a seller that does not join (and pay commission). Thus, the amount sellers are willing to pay reflects their profit margin on incremental sales and how many buyers use M. Yet the ultimate result is the same: Sellers are willing to pay well beyond M's cost to receive business through M, which pushes up retail prices and ultimately shifts surplus from consumers to M, while buyers pay nothing for M's service, resulting in excessive usage of it.

For an intermediary that helps match buyers and sellers, price coherence offers the additional benefit of discouraging strategic behavior by buyers. In principle, a buyer might obtain information from an intermediary but then make a purchase directly from the recommended seller, yielding no fee to the intermediary. By assuring that prices are equal for intermediated and direct purchases, price coherence eliminates a buyer's incentive to use this approach. In cases where the intermediary lowers the overall cost of matching, this rationale could provide an efficiency justification for an intermediary imposing price coherence. Of course, one can imagine other structures that also address the intermediary's concern. For example, the intermediary could insist on a suitable contract between intermediary and buyer before the intermediary provides information or a recommendation. Indeed, real estate buyer's agents (Section A.6) use both price coherence along with contracts wherein buyers and sellers agree not to circumvent intermediaries. Alternatively, an intermediary could charge buyers for its information service rather than for completed transactions. That said, as noted previously, such upfront fees are seldom used.

7 Policy implications and conclusion

Consumers often view price coherence as a bonus—no extra fee to pay by credit card, to book a plane ticket through a travel agent, or to buy insurance through a broker. Indeed, many readers of this paper probably enjoy credit card rebates and other benefits resulting from price coherence. Of course consumers ultimately *do* pay the associated costs: In equilibrium, prices increase to cover sellers costs of offering "free" benefits. Moreover, including these services in the base price encourages over-consumption. Specifically, we showed that an intermediary always imposes price coherence if it has the ability to do so, as this increases its profit although on reasonable assumptions it lowers consumer surplus and sometimes welfare (Propositions 3 and 2). We also showed that this effect persists and even grows when multiple intermediaries compete (Proposition 7). We further demonstrated that the intermediary continues to destroy consumer surplus even when it possesses superior information about the seller best suited to a given buyer (Proposition 10). We grounded these theoretical findings in six distinct markets where price coherence is prominent (Section 2).

Even if new intermediaries enter, or even if regulators succeed in increasing competition (e.g. by blocking a merger or imposing horizontal separation), our results indicate that outcomes will not improve and could worsen. Comparing Proposition 7 with Propositions 3 and 2 indicates that in the case of competing intermediaries, price coherence reduces consumer surplus and welfare by at least the amount of net benefit created by the intermediary, whereas in the single-intermediary case, the harm was limited to buyers' joining costs. This reflects that competition between intermediaries under price coherence causes them to focus on offering maximal *gross* benefits to buyers, resulting in them investing to the point where they create no *net* benefit.

Tellingly, competition and consumer protection regulators have been drawn to markets with price coherence. Of the six markets we examined, competition cases and regulatory investigations have occurred or are ongoing in five (travel booking, payment cards, insurance, online marketplaces, and search engine advertising). Regulators' concern is more than coincidental: By offering benefits to buyers at no direct charge, intermediaries cause excessive usage of their services—usage which then lets intermediaries extract significant fees from sellers, indeed beyond even the normal monopoly fees.

A natural regulatory response in affected markets is to end whatever regulation, contract provision, or other rigidity enforces price coherence, assuming that it is feasible to do so. Our model confirms the basic wisdom of this approach, but we note that favorable outcomes are not guaranteed. For example, regulatory action in Australia in 2003 stopped card schemes from imposing price coherence and required card schemes to inform merchants of their right to surcharge. Many Australian merchants subsequently added credit card fees, although these were on average double what credit card acquirers charged to merchants, suggesting that they used surcharges to exploit buyers held up at the point of sale. More generally, we assumed that in the absence of price coherence, sellers face no other frictions in passing on intermediation costs to buyers. In principle this neutrality need not hold. For example, menu costs or other frictions could inhibit pass-through even if intermediaries are not allowed to impose price coherence. In that case, our results on the impact of intermediation may hold even without price coherence, and the benefits of banning price coherence may be overstated. It is therefore by no means clear that banning price coherence rules necessarily leads to better outcomes.

Relatedly, regulation could seek to separate charges for the underlying product or service, versus charges for the intermediary's service. Recent changes to insurance and financial services sales practices in Australia, Singapore, and the UK typify this approach. In this case, a consumer must compare offerings that each have two separate prices—the base service plus the intermediary's fee—but competition among intermediaries may be more likely to reduce the latter, and the resulting market structure may better facilitate direct purchases by some portion of consumers. Indeed, Singapore's regulatory intervention explicitly seeks to facilitate direct purchases—requiring every insurer to make "basic insurance" available directly to consumers, bypassing agents and other intermediaries.

Alternatively, regulators could directly oversee the fees that intermediaries charge to sellers. Some countries have already implemented this approach in the case of credit card networks by regulating interchange fees, including European caps on both credit and debit interchange fees (per the EC's July 2013 announcement, with changes to phase in over the coming months) and the US 2010 Durbin Amendment (15 USC §1693o-2) limiting debit card interchange fees. Similarly, in the context of financial service commissions, some regulators simply disallowed certain payments from sellers to intermediaries—requiring that an intermediary's fees be borne solely by the buyers who choose to use the intermediary's services. (The online appendix presents specific regulations embodying this approach.) Direct oversight of fees presents clear problems, most notably a regulator's difficulty in determining the "right" fee, a price-setting function that is viewed as unduly intrusive in most markets. That said, the two-sided structure of these markets offers some protection against regulatory error: If a regulator set too low a price on one side of the market, an intermediary could in most cases still recover costs from the other side of the market. In our setting, requiring that the intermediary's fee be borne solely by its buyers is equivalent to eliminating price coherence. Such a requirement always increases consumer surplus and, in most cases, increases welfare.

Though our model considers only static outcomes, markets with price coherence tend to feature notable dynamics. For one, improved technology often makes direct purchases easier. For example, the Internet lets airlines sell tickets from their own web sites, and some home sellers use the Internet to market their properties—reducing the relative importance of reservation systems and brokers. These advances constrain intermediaries' fees. At the same time, other factors can push intermediaries' fees higher. Most notably, competition among intermediaries can spur higher benefits or rebates to buyers and, in turn, higher fees to sellers. This pattern seems to have occurred with payment cards in the U.S., as well as with travel booking networks, certain insurance brokers, search engines, and online restaurant ordering (an example presented in the online appendix). Fees are limited primarily by the potential feasibility of direct purchases. But in the short run, price coherence suppresses any incentive for direct purchases, preventing a seller from using the intermediary while offering a savings for direct purchases. With many or most buyers flowing through an intermediary, sellers predictably hesitate to leave the intermediary's platform, even when fees rise considerably.

Price coherence itself can be subject to notable change over time. One might expect a platform to impose price coherence only when it achieves significant market power, as it might be difficult to impose price coherence as a new entrant. Yet in practice we observe that in many countries, payment cards imposed price coherence from the outset. Price coherence also began at the outset in travel reservation services and in online restaurant ordering. If each buyer signs up with only a single intermediary, then even a small or new entrant intermediary has market power as to its buyers, when dealing with sellers that want to reach those buyers. This may explain why even small intermediaries succeed in imposing price coherence.

A further important dynamic effect of price coherence is its facilitation of an intermediary's launch.

At the outset, a new intermediary typically connects few users, lacking the network effects benefits that would deliver greater value to users if the intermediary were larger. As a result, buyers often find a new intermediary too low in value to justify the cost of joining and any fee to cover the intermediary's costs, which leads the intermediary to struggle to get traction. With price coherence, the intermediary need only achieve *positive* value—a much lower threshold which both facilitates consumer usage and helps the intermediary achieve scale.

Despite the many concerns prompted by price coherence, the intermediaries at issue nonetheless tend to provide significant benefits. One can hardly overstate the impact of airline reservation systems, particularly upon their launch in the 1970's when they constituted the largest private computer network in the world (eclipsed only by the U.S. Department of Defense). Credit cards and insurance brokers can offer similar benefits to the buyers and sellers who most value their services. But price coherence causes the costs of these services to be paid by all, including those who prefer lower-cost alternatives. The resulting market structure, we argue, is ripe for further examination.

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9 Appendix: Proofs

This appendix provides proofs of all results.

9.1 Proof of Proposition 1

Suppose M sets $k \geq 0$, $p_B \geq 0$ and $p_S \geq 0$ in stage 1. Define $\beta = b(k) - p_B - p_S$. Consider first $\beta > 0$. Consider buyers' and sellers' equilibrium strategies in stage 2. These are: (i) buyers join M if and only if $\beta \geq c$; (ii) both sellers join M; and (iii) each seller i sets the prices $p_i^d = d + t$ and $p_i^m = d + t + p_S$, for direct purchases and purchases through M respectively.

To show that (i)-(iii) characterize an equilibrium in the stage 2 subgame, note first that buyers always complete a purchase. Even if a buyer has the maximal mismatch with the seller in question and pays the price $d+t$ to purchase directly, the buyer's surplus is $v - d - 2t$, which is positive. Given (ii)-(iii), buyers pay $p_B + p_S$ more if they want to buy through M and incur the cost c of joining, but get the extra benefit $b(k)$, so (i) follows.

A seller will do worse by not joining M. A seller can always pass through the higher cost p_S so as to maintain the same margin as if buyers purchase directly, but given $\beta > 0$, the seller attracts more buyers through M since the seller can offer a greater surplus to such buyers. Thus, (ii) holds.

To show why (iii) holds, consider first the problem for seller i in the standard Hotelling analysis in which no buyers join M. Because the other seller sets the standard Hotelling equilibrium price of $d+t$, seller i chooses p_i to solve:

$$\max_{p_i} (p_i - d)\left(\frac{1}{2} + \frac{d+t-p_i}{2t}\right). \tag{6}$$

Seller i's best response is to set $p_i = d+t$. In equilibrium, each seller obtains the standard Hotelling profit of $\pi_1 = \pi_2 = \frac{t}{2}$.

Now allow buyers to join M, and suppose seller i sets prices so that $p_i^m - p_i^d \leq b(k) - p_B$. Then buyers who join M buy using M. Given the other seller sticks to its equilibrium strategy, seller i's profit is

$$\max_{p_i^d, p_i^m} \left((1 - G(\beta))\left(p_i^d - d\right)\left(\frac{1}{2} + \frac{d+t-p_i^d}{2t}\right) + G(\beta)\left(p_i^m - d - p_S\right)\left(\frac{1}{2} + \frac{d+t+p_S-p_i^m}{2t}\right)\right).$$

Note that seller i's profit is separable into profit from buyers purchasing directly and profit from those coming through M. The standard Hotelling analysis applies to both profit terms (in the latter case by setting the seller's cost equal to $d+p_S$). This implies seller i does best setting $p_i^d = d+t$ and $p_i^m = d+t+p_S$, so as to obtain the standard Hotelling profits. Note that seller i does worse by setting prices so that $p_i^m - p_i^d > b(k) - p_B$, which would make all buyers that choose seller i prefer to buy directly. Seller i's deviation profit in this case is

$$\max_{p_i^d} \left((1 - G(\beta))\left(p_i^d - d\right)\left(\frac{1}{2} + \frac{d+t-p_i^d}{2t}\right) + G(\beta)\left(p_i^d - d\right)\left(\frac{1}{2} + \frac{d+t-p_i^d-\beta}{2t}\right)\right).$$

Comparing this to (6) and recalling that $\beta > 0$, seller i's resulting profit must be strictly less than the standard Hotelling profit. Thus, (iii) holds.

Equilibria in the continuation game in which one seller does not join can be ruled out given such a seller can always do better joining, passing through the extra costs and making some additional profitable sales (given $\beta > 0$). The only other equilibrium in the continuation game is the trivial equilibrium. Given the equilibrium selection rule adopted, the equilibrium in (i)-(iii) prevails provided M can obtain a positive profit, which is confirmed below.

In stage one, M sets $p_B \geq 0$ and $p_S \geq 0$ to maximize $(p_B + p_S - k)\, G(b(k) - p_B - p_S)$. Without loss of generality, set $p_B = 0$. If $k < k^m$, then by increasing k to k^m and increasing p_S by an equal amount, M's margin on each sale would remain unchanged, but M would sell more units since $b(k)$ would increase by more than p_S given that $b'(k) > 1$ for $k < k^m$. By the same logic, if $k > k^m$, then M can always increase its profit by lowering k to k^m. Thus, M's optimization requires $b'(k) = 1$, so M sets the efficient investment k^m. M's task then becomes choosing p_S to maximize $(p_S - k^m)\, G\,(b\,(k^m) - p_S)$. This is a standard monopoly pricing problem. Since G is differentiable and log-concave, M chooses p_S to solve the usual first-order condition, i.e. (1). Given that $\pi^m = b(k^m) - k^m > 0$, p_S satisfies $k^m < p_S < b(k^m)$. This ensures that $\beta > 0$ and that M obtains a positive profit.

Finally, note that M would never set fees such that $\beta \leq 0$ since following the analysis above, buyers would never expect to get any surplus from joining M, and so no buyers would join, leaving M with no profit.

9.2 Proof of Proposition 2

With price coherence, $p_i^m = p_i^d$. Denote seller i's common price p_i. Suppose M sets $0 \leq k \leq \overline{k}$, $p_B \geq 0$ and $p_S \geq 0$ in stage 1.[16] Consider buyers' and sellers' equilibrium strategies in stage 2. These are: (i) buyers join M if and only if $b(k) - p_B \geq c$ and $\beta \geq 0$; (ii) if $\beta \geq 0$ then each seller joins M and set the price $\widehat{p} = d + t + G(b(k) - p_B)p_S$; (iii) if $\beta < 0$ then neither seller joins M and each seller prices at $d + t$.

To show that (i)-(iii) characterize an equilibrium in the stage 2 subgame, note first that buyers always complete a purchase. Consider the least favorable case: a buyer has the maximal mismatch with the seller in question and does not purchase through M, so pays the maximum possible price $d + t + b(\overline{k})$ which would arise if $p_S = b(k)$ and $p_B = 0$ and k is set to the highest possible level at which M still breaks even. In that case, the buyer's surplus is $v - d - 2t - b(\overline{k})$, which is positive. Given price coherence, buyers pay p_B more if they want to buy through M, but get the extra benefit $b(k)$, so are willing to join whenever sellers are expected to join (i.e. $\beta \geq 0$) and $b(k) - p_B \geq c$. This establishes (i).

Suppose $\beta \geq 0$. If both sellers join and set the proposed equilibrium price, they obtain the standard Hotelling profits. Now suppose seller i deviates, does not join M, and sets the price p_i'. Its deviation profit is

$$\max_{p_i'} \left\{ \begin{array}{c} G(b(k) - p_B)(p_i' - d) \left(\frac{1}{2} + \frac{\widehat{p} - p_i' - (b(k) - p_B)}{2t} \right) \\ +(1 - G(b(k) - p_B))(p_i' - d) \left(\frac{1}{2} + \frac{\widehat{p} - p_i'}{2t} \right) \end{array} \right\}, \tag{7}$$

[16] Note $k \leq \overline{k}$ since at any higher k, even if M can extract the full benefit buyers obtain from going through M in its fees and even if all buyers join, M would make a loss.

which after substituting in $\widehat{p}$ and rearranging terms, can be written as[17]

$$\max_{p_i'}(p_i' - d)\left(\frac{1}{2} + \frac{d + t - p_i'}{2t} - \frac{G(b(k) - p_B)\beta}{2t}\right). \tag{8}$$

Compare the profit in (8) with the profit in (6). The profit expression is the same, with the same margin, with demand the same if $\beta = 0$ and lower if $\beta > 0$. Since the profit in (6) is the same as the profit in the proposed equilibrium (i.e. standard Hotelling profit), each seller i is willing to join M given $\beta \geq 0$ and that buyers and the other seller follow their equilibrium strategies. This establishes (ii).

In case $\beta < 0$, the above analysis implies that the deviation profit of seller i is higher than the standard Hotelling profit and so there is no equilibrium in which both sellers join M. The trivial equilibrium still holds. The standard Hotelling analysis applies, and both sellers price at $d + t$ in equilibrium. This establishes (iii).

Regardless of whether $\beta \geq 0$ or $\beta < 0$, the equilibrium in the continuation game in which one seller joins M and the other does not can be ruled out.[18] Given the equilibrium selection rule adopted, the equilibrium in (i)-(ii) prevails if $\beta \geq 0$ provided M obtains a positive profit, which is confirmed below. The equilibrium in (iii) is unique if $\beta < 0$.

In stage one, M sets $p_B \geq 0$ and $p_S \geq 0$ to maximize the resulting profit $(p_B + p_S - k)\, G\,(b\,(k) - p_B)$ subject to $p_S \leq b(k) - p_B$. This is maximized by setting $p_B = 0$ and $p_S = b(k)$. Thus, M chooses k to maximize its profit $(b(k) - k)G(b(k))$. Denote M's preferred choice k^*. Since $G(b(k))$ is increasing in k at k^m, $k^* > k^m$. Moreover, since $b(k) - k$ is decreasing for $k > k^m$ and reaches zero when $k = \overline{k}$, it must be that $k^* < \overline{k}$ so that M obtains a positive profit. Given G is log-concave in its argument and $b(k)$ is strictly concave in k, the function $(b(k) - k)G(b(k))$ is log-concave in k, implying there exists a unique k^* satisfying these properties. The remaining properties of the equilibrium outcome stated in the proposition follow by substituting M's optimal choices into (i)-(iii).

9.3 Proof of Proposition 3

The results in the Proposition follow from a direct comparison of the equilibrium outcomes in Propositions 1 and 2. The comparisons are also detailed in the text following the statement of the Proposition.

[17] The assumptions that $t > b(\overline{k})$ and $\beta \geq 0$ ensure that each of the market shares in (7) lies between 0 and 1 at seller i's optimal deviation price.

[18] The lengthy proof is provided in the online appendix B.

9.4 Proof of Proposition 4

The welfare contribution of M without price coherence is positive, since buyers face a fee for going through M that exceeds k^m, so buyers only join if they contribute positively to welfare.

If $G(c)$ is the power function $G(c) = \left(\frac{c}{\bar{c}}\right)^\alpha$, where $\alpha > 0$, then the welfare contribution of M under price coherence is $W_M = \int_0^{b(k^*)} (b(k^*) - k^* - c)\, dG(c)$, so $W_M = \left(\frac{b(k^*)}{\bar{c}}\right)^\alpha \left(\frac{1}{1+\alpha} b(k^*) - k^*\right)$. This is negative if $\frac{b(k^*)-k^*}{k^*} < \alpha$.

9.5 Proof of Corollary 1

The proofs of Propositions 1-3 continue to hold in case of a rebate. The rebate is only relevant when price coherence holds. In that case, the final paragraph of the proof of Proposition 2 has to be modified. M now solves $\max_{p_B, p_S \geq 0} (p_B + p_S - k)\, G\,(b\,(k) - p_B)$ subject to $p_S \leq b\,(k) - p_B$. Substituting in the constraint on p_S which must be binding, M's problem becomes $\max_{p_B} (b\,(k) - k)\, G\,(b\,(k) - p_B)$. This implies it sets $k = k^m$, $p_B = b(k^m) - \bar{c} < 0$ and $p_S = \bar{c}$ in stage one. This ensures all buyers join, and M obtains the maximum possible profit of π^m. Prices are higher by $\bar{c}$ as a result of M, which exactly offsets the additional benefits buyers enjoy. Each buyer is therefore worse off by their joining costs. Consumer surplus is lowered by $E[c]$ as a result of M. Thus, Proposition 3 holds except there is no longer any over-investment in buyer-side benefits. M's contribution to welfare under price coherence is $W_M = \int_0^{\bar{c}} (b(k^m) - k^m - c) dG(c)$, so if $G(c)$ is the power function $G(c) = \left(\frac{c}{\bar{c}}\right)^\alpha$ this becomes $W_M = b(k^m) - k^m - \frac{\alpha \bar{c}}{1+\alpha}$. Since $\bar{c} > b(k^m)$, this contribution is bounded by $b(k^m) - k^m - \frac{\alpha b(k^m)}{1+\alpha}$, which can be rewritten as $\frac{1}{1+\alpha}(b(k^m) - (1+\alpha)k^m)$. But $\frac{b(k^m)-k^m}{k^m} < \alpha$ is equivalent to $b(k^m) - (1+\alpha)k^m < 0$ so Proposition 4 continues to hold with k^* replaced by k^m.

9.6 Proof of Corollary 2

The fixed fee F is only relevant when price coherence holds. The proof of Proposition 2 can be modified to handle buyers facing a fixed fee, with buyers' joining decision based on $p_B + F$ rather than just p_B. The modified conditions $\bar{c} > b(max(\bar{k}, k^F))$, $t > b(max(\bar{k}, k^F))$ and $v > d + t + b(max(\bar{k}, k^F))$ handle the possibility that $k^F > \bar{k}$.

The main change to the proof of Proposition 2 is to the final paragraph. M chooses to set the transaction fee p_B to zero, as before, but will want to make use of the fixed fee. It therefore chooses k and F to maximize $(b(k) - k + F)\, G\,(b\,(k) - F)$. Consider the choice of k. If $k = k_0$ such that $b'(k_0) > \frac{1}{2}$, then M can always increase profit by increasing k to k_1 where $b'(k_1) = \frac{1}{2}$ and increasing F

from F_0 to F_1 such that $F_1 - F_0 = b(k_1) - b(k_0)$. This increases M's profit by

$$\begin{aligned} & (b(k_1) - k_1 + F_1) G(b(k_1) - F_1) - (b(k_0) - k_0 + F_0) G(b(k_0) - F_0) \\ = & (b(k_1) - b(k_0) - (k_1 - k_0) + F_1 - F_0) G(b(k_0) - F_0) \\ = & (2(b(k_1) - b(k_0)) - (k_1 - k_0)) G(b(k_0) - F_0), \end{aligned}$$

which is positive since $b'(k) > \frac{1}{2}$ for $k_0 \leq k < k_1$. By the same logic, if $b'(k_0) < \frac{1}{2}$, then M can always increase its profit by lowering k such that $b'(k) = \frac{1}{2}$. Thus, M chooses to set $k = k^F$, where $b'(k^F) = \frac{1}{2}$, so over-invests in buyer-side benefits.

M's decision then becomes choosing F to maximize $\left(F + b(k^F) - k^F\right) G\left(b\left(k^F\right) - F\right)$. This is a standard monopoly pricing problem where the monopolist has marginal cost $k^F - b(k^F)$. Since G is differentiable and log-concave, M's optimal choice of F, denoted F^*, is defined by the solution to the usual first-order condition (4).

Clearly, M will continue to want to impose price coherence if permitted to do so. Indeed, the fixed fee will enable M to extract additional surplus from buyers. Compared to the case without M, prices end up higher by $G\left(b(k^F) - F^*\right) b(k^F)$, which reduces surplus for all buyers. On the other hand, $G\left(b(k^F) - F^*\right)$ buyers purchase through M and get the benefit $b(k^F) - F^*$. The net effect is a loss of consumer surplus of $G\left(b(k^F) - F^*\right) F^*$, in addition to the costs buyers incur in joining, $\int_0^{b(k^F)-F^*} c dG(c)$.

If the buyer participation cost is distributed according to the power function, then buyers with $c \leq c_1 = b(k^F) - F^* = \frac{\alpha}{1+\alpha}(2b(k^F) - k^F)$ join M while the first-best outcome requires buyers with $c \leq c_2 = b(k^m) - k^m$ join M. Compare c_1 with c_2. Define $\theta(k) = \frac{\alpha}{1+\alpha}(2b(k) - k)$, and notice that $\theta(k)$ is maximized at k^F. Therefore, $\theta(k^F) \geq \theta(k^m)$. A sufficient condition for $c_1 > c_2$ is $\theta(k^m) > b(k^m) - k^m$, which requires $\frac{\alpha}{1+\alpha}(2b(k^m) - k^m) > b(k^m) - k^m$. A sufficient condition is $\alpha \geq 1$, or if $\alpha < 1$, then $\frac{b(k^M)-k^M}{k^M} < \frac{\alpha}{1-\alpha}$.

M's contribution to welfare is $W_M = \int_0^{b(k^F)-F^*} \left(b(k^F) - k^F - c\right) dG(c)$. If $G(c)$ is the power function, $F^* = \frac{\alpha k^F + (1-\alpha) b(k^F)}{1+\alpha}$. This implies $W_M < 0$ if and only if $\frac{b(k^F)-k^F}{k^F} < \frac{\alpha}{1+\alpha^2}$.

9.7 Proof of Corollary 3

Set $b(k) = 0$ for all k and apply Corollary 1. M prefers to provide a rebate to buyers of no less than $\bar{c}$. This ensures all buyers join. The results then follow directly given M's profit is $\pi_A - k$, buyers (in aggregate) face joining costs of $E[c]$ but no net benefit arising from M's existence, and $k < \pi_A < E[c]$.

9.8 Proof of Proposition 5

Suppose each M^i $(i = 1, 2)$ sets $k^i \geq 0$, $p_B^i \geq 0$ and $p_S^i \geq 0$ in stage 1. Define $\beta^i = b\left(k^i\right) - p_B^i - p_S^i$. Suppose first $\beta^i > 0$ for $i = 1, 2$. Consider buyers' and sellers' equilibrium strategies in stage 2. These are: (i) buyers join M^1 if $\beta^1 \geq c$ and $\beta^1 > \beta^2$; buyers join M^2 if $\beta^2 \geq c$ and $\beta^2 > \beta^1$; buyers randomize between M^1 and M^2 if $\beta^1 \geq c$ and $\beta^1 = \beta^2$ (otherwise, they do not join either intermediary); (ii) both sellers join M^1 and M^2; and (iii) each seller sets the price $p^d = d + t$ for buyers that purchase directly and the prices $p^j = d + t + p_S^j$ for buyers that purchase through M^j.

To show that (i)-(iii) characterize an equilibrium in the stage 2 subgame, note first that buyers always complete a purchase. Even in the least favorable case—a buyer has the maximal mismatch with the seller in question and does not purchase through either intermediary (so pays the price $d+t$)—the buyer's surplus is $v - d - 2t$, which is positive. Given (ii)-(iii), buyers pay $p_B^i + p_S^i$ more if they want to buy through M^i and incur the cost c of joining, but get the extra benefit $b(k^i)$, so (i) follows. (Note joining both intermediaries would require a buyer to incur the cost c twice with no extra benefit, so can be ruled out).

Sellers can never do better by not joining one of the intermediaries, say M^i. A seller can always pass through the higher cost p_S^i so as to maintain the same margin as if buyers purchase directly, but given $\beta^i > 0$ the seller attracts at least as many buyers by joining M^i since the seller can offer a greater surplus to any buyers that have joined M^i. Thus, (ii) holds.

To show why (iii) holds, first note that if $\beta^j < \beta^i$ then no buyers join M^j and so the sellers cannot do better than set the prices p^j given in (iii). If $\beta^j > \beta^i$, then buyers join M^j if they join at all, and the proof of (iii) follows exactly as in the proof of Proposition 1 with p_i^m replaced by p_i^j, p_S replaced by p_S^j, and β replaced by β^j. In case $\beta^j = \beta^i$, sellers expect an equal number of buyers join each intermediary, and given the other seller sticks to its equilibrium strategy, seller i's profit is separable into the profit from buyers purchasing directly, from buyers purchasing through M^1 and from buyers purchasing through M^2. The same analysis applies to each profit expression following the proof of Proposition 1, which establishes (iii).

In case $\beta^i \leq 0$ for any i, the above analysis implies no buyers would join M^i, so M^i will make no profit and would not choose such fees.

In stage one, each M^i knows it only receives positive demand if $\beta^i \geq \beta^j$ and $\beta^i > 0$. Since starting from $\beta^i = \beta^j$, M^i can take the whole market rather than half the market if it increases β^i by an infinitesimal amount, it always wants to do so provided its margin remains positive. As a result, in equilibrium, M^i offers the maximum possible β^i consistent with cost recovery (i.e. $p_B^i + p_S^i \geq k^i$). This is achieved by setting $k^i = k^m$ and $p_B^i + p_S^i = k^m$ for $i = 1, 2$. Without loss of generality, set $p_B^i = 0$, so $p_S^i = k^m$ for $i = 1, 2$. The intermediaries make zero profit in equilibrium. The remaining properties of the equilibrium outcome stated in the proposition follow by substituting the intermediaries' equilibrium choices in stage one into (i)-(iii).

The above equilibrium no longer holds if intermediaries can impose price coherence. Suppose M^1 deviates and imposes price coherence in stage 1. It can continue to invest k^m, charge sellers a fee just above k^m, and charge nothing to buyers. Sellers that join M^1 must set a single price for all buyers, implying buyers strictly prefer to join M^1 over M^2 if sellers join both intermediaries. Such buyers get the same benefit $b(k^m)$ but avoid the extra fee from sellers. With $G(b(k^m))$ buyers expected to join M^1 exclusively, sellers will be willing to join M^1 as shown in the proof of Proposition 2. Given sellers join both intermediaries whenever this is an equilibrium in the stage 2 subgame, the selected equilibrium has $G(b(k^m))$ buyers joining M^1 exclusively, sellers joining both intermediaries, with M^1 making a positive profit. Thus, each intermediary, acting unilaterally, wants to impose price coherence and charge higher fees.

9.9 Proof of Proposition 6

With price coherence imposed by both intermediaries, $p_i^1 = p_i^2 = p_i^d$, and denote seller i's common price p_i. Extending the approach taken in the proof of Proposition 2, suppose each M^i $(i = 1, 2)$ sets $0 \leq k^i \leq \overline{k}$, $p_B^i \geq 0$ and $p_S^i \geq 0$ in stage 1. Consider buyers' and sellers' equilibrium strategies in stage 2. These are: (i) if $\beta^i \geq 0$ and $b(k^i) - p_B^i > b(k^j) - p_B^j$, then buyers only join M^i (doing so if they draw $c \leq b(k^i) - p_B^i$) and sellers join both intermediaries and set the price $\widehat{p}^i = d + t + G(b(k^i) - p_B^i)p_S^i$; (ii) if $\beta^i \geq 0$, $\beta^j < 0$ and $b(k^i) - p_B^i \leq b(k^j) - p_B^j$, then the same strategies hold as in (i) except sellers only join M^i; (iii) if $\beta^1 \geq 0$, $\beta^2 \geq 0$ and $b(k^1) - p_B^1 = b(k^2) - p_B^2$, which can be denoted $b(k) - p_B$, then buyers join an intermediary if they draw $c \leq b(k) - p_B$, randomizing over which one, while both sellers join both intermediaries and set the price $\widehat{p} = d + t + G(b(k) - p_B)\left(\frac{p_S^1}{2} + \frac{p_S^2}{2}\right)$; (iv) if $\beta^1 < 0$ and $\beta^2 < 0$, then no buyers or sellers join either intermediary, and each seller prices at $d + t$.

To show that (i)-(iv) characterize an equilibrium in the stage 2 subgame, note first that buyers always complete a purchase. This follows by the same reasoning as given in the proof of Proposition 2.

Consider case (i). Buyers strictly prefer to join M^i over M^j, and do so whenever they draw $c \leq b(k^i) - p_B^i$. Given buyers only join M^i, sellers' optimal strategies are determined exactly as in case (ii) in the proof of Proposition 2 in which there is a single intermediary, so they are willing to join M^i if and only if $\beta^i \geq 0$, and they set the price $\widehat{p}^i = d + t + G(b(k^i) - p_B^i)p_S^i$. The only difference is that sellers also join M^j given they cannot do better not joining M^j. This establishes (i).

Consider case (ii). If buyers are expected to join M^j, the proof of Proposition 2 implies that sellers will not want to join M^j. With sellers only joining M^i, the same analysis as case (i) applies. This establishes (ii).

Consider case (iii). Given sellers join both intermediaries, buyers that join an intermediary are indifferent between joining M^1 and M^2 since they face the same benefits from going through each intermediary and the same seller price due to price coherence. They therefore cannot do better than to randomize between the two intermediaries, meaning half the buyers that join an intermediary will join each one. Given the other seller has joined both intermediaries and prices at $\widehat{p}$, if seller i does likewise it obtains the standard Hotelling profit. If it deviates and does not join either intermediary and sets its price to be p_i', its deviation profit is equivalent to (7). Substituting in $\widehat{p}$ from (iii), its deviation profit can be written as

$$\max_{p_i'} (p_i' - d) \left(\frac{1}{2} + \frac{d + t - p_i'}{2t} - \frac{G(b(k) - p_B) \left(\frac{\beta^1 + \beta^2}{2} \right)}{2t} \right). \tag{9}$$

Compare the profit in (9) with the profit in (6). The profit expression is the same, with the same margin and demand at every price if $\beta^1 + \beta^2 = 0$, but lower demand if $\beta^1 + \beta^2 > 0$. Thus, since the profit in (6) is the same as the profit in the proposed equilibrium (i.e. standard Hotelling profit), each seller i does not want to deviate in this way given $\beta^1 \geq 0$ and $\beta^2 \geq 0$ and that buyers and the other seller follow their equilibrium strategies.

The alternative deviation is that seller i only joins one intermediary, say M^j, and sets its price to be p_i' for buyers purchasing through M^j or directly. Then seller i's deviation profit is

$$\max_{p_i'} \left\{ \begin{array}{c} \frac{1}{2} G\left(b\left(k\right) - p_B\right) \left(p_i' - d\right) \left(\frac{1}{2} + \frac{\widehat{p} - p_i' - (b(k) - p_B)}{2t} \right) \\ + \frac{1}{2} G\left(b\left(k\right) - p_B\right) \left(p_i' - d - p_S^j\right) \left(\frac{1}{2} + \frac{\widehat{p} - p_i'}{2t} \right) \\ + \left(1 - G\left(b\left(k\right) - p_B\right)\right) \left(p_i' - d\right) \left(\frac{1}{2} + \frac{\widehat{p} - p_i'}{2t} \right) \end{array} \right\}. \tag{10}$$

Substituting the expression for $\widehat{p}$ from (iii) above into (10), and solving for the optimal p_i', seller i still sells to some of the buyers who join M^i (i.e. the expression in the first line of (10) is positive) given our assumption that $t > b(\overline{k})$. The difference between the resulting deviation profit and the standard

Hotelling profit is

$$\frac{\left(\beta^{i}\right)^{2} G(b(k)-p_{B})-8t\beta^{i}-4\left(b\left(k\right)-p_{B}\right)p_{S}^{j}G(b(k)-p_{B})}{32t}. \tag{11}$$

Given $t > b(\overline{k}) > \beta^{i} \geq 0$ and given $b\left(k\right) - p_{B} \geq 0$ since $\beta^{j} \geq 0$, the expression in (11) is strictly negative. Thus, seller i is strictly worse off deviating in this way, which establishes (iii).

Consider case (iv). The same analysis as above implies that there is no equilibrium in which both sellers join both intermediaries. The trivial equilibrium is selected instead in which buyers and sellers do not join either intermediary. The standard Hotelling analysis applies, and both sellers price at $d+t$ in equilibrium. This establishes (iv).

In stage one, each M^{i} only expects to receive positive demand if $b(k^{i}) - p_{B}^{i} \geq b(k^{j}) - p_{B}^{j}$ and $\beta^{i} \geq 0$. Since starting from $b(k^{1}) - p_{B}^{1} = b(k^{2}) - p_{B}^{2}$, M^{i} can take the whole market rather than half the market if it increases $b(k^{i}) - p_{B}^{i}$ by an infinitesimal amount, it always wants to do so provided its margin remains positive. As a result, in equilibrium, M^{i} offers the maximum possible $b(k^{i}) - p_{B}^{i}$ consistent with cost recovery (i.e. $p_{B}^{i}+p_{S}^{i} \geq k^{i}$) and $\beta^{i} \geq 0$. This is achieved by setting $k^{i} = \overline{k}$, $p_{B}^{i} = 0$ and $p_{S}^{i} = b(\overline{k})$. Both intermediaries do so, and so the intermediaries make zero profit in equilibrium. To confirm this is an equilibrium in stage 1, note that setting any $p_{B}^{i} > 0$ would require k be set such that $b(k) = b(\overline{k}) + p_{B}^{i}$ to avoid all joined buyers switching to M^{j}, but then M^{i}'s margin on each sale would be $b(k) - k < 0$ so M^{i} would make a loss. Similarly, if M^{i} tries to increase k, then $b(k) - k < 0$, so even if it could recover $b(k)$ from sellers, it would make a loss. M^{i} cannot charge more to either seller without the seller dropping out. Moreover, M^{i} cannot attract any profit if it tries to lower k given joining buyers would only join M^{j} (and sellers would continue to join M^{j}). Finally, M^{i} cannot make a positive profit by dropping the price coherence restriction. If M^{i} did so, it could charge buyers directly and/or reduce the benefits offered to buyers instead of charging sellers. But M^{j} imposes price coherence, so this deviation would cause all buyers to purchase exclusively from M^{j}.

The remaining properties of the equilibrium outcome stated in the proposition follow by substituting the intermediaries' equilibrium choices in stage one into (i)-(iv).

9.10 Proof of Proposition 7

From Propositions 5-6, the intermediaries make zero profit with or without price coherence, so welfare always equals consumer surplus. Without price coherence, M's contribution to consumer surplus and welfare is $\int_{0}^{\pi^{m}}(\pi^{m}-c)dG(c)$. With price coherence, M's contribution is $-\int_{0}^{b(\overline{k})}cdG(c)$. The results in the proposition follow directly by comparing these contributions.

9.11 Proof of Proposition 8

Suppose M sets fees $p_B \geq 0$ and $p_S \geq 0$ in stage 1, with $p_B + p_S > k$ since otherwise M will not make a positive profit. Consider buyers' and sellers' equilibrium strategies in stage 2. These are: 2(i) buyers join M if and only if $p_B + p_S + c \leq s$ (otherwise they search and buy directly); 2(ii) both sellers join; and 2(iii) each seller sets the prices $p^d = d + t$ and $p^m = d + t + p_S$. Also consider the equilibrium strategies of buyers and M in stage 3. These are: 3(i) buyers that join M follow M's recommendation of which seller to choose; and 3(ii) M recommends each buyer chooses the seller that provides the buyer with the highest net utility from among the sellers that join. (If neither seller joins, M randomly selects a seller to recommend to the buyer.)

To show that 3(i)-3(ii) characterize an equilibrium in the stage 3 subgame, note that for any p_B and p_S, buyers expect both sellers to join M and to set symmetric prices in stage 2. Buyers that join M will therefore want to follow M's recommendation, given M plays its equilibrium strategy in 3(ii) and recommends the seller that is best for the buyer. Thus, 3(i) follows. To show that M prefers to follow the strategy in 3(ii), note that since buyers follow M's advice, M will collect $p_B + p_S - k > 0$ regardless of which seller the buyer purchases from, and being indifferent, M cannot do better than to recommend the seller that is best for the buyer. In case only one seller joins, M strictly prefers to recommend that seller so it can make $p_B + p_S - k > 0$ on sales through that seller, rather than nothing for sales through the other seller. If no sellers join, M will not obtain any profit regardless of what buyers do, and so in the absence of information on the best match for each buyer, M cannot do better than to randomly select one of the sellers to recommend.

To show that 2(i)-2(iii) characterize an equilibrium in the stage 2 subgame, note first that buyers will always complete a purchase (even if they randomly select a seller and buy directly), for the same reason as in the proof of (i) in Proposition 1. Given 2(ii)-2(iii) and 3(ii), buyers pay $p_B + p_S$ more if they want to buy through M and incur the cost c of joining, but avoid the cost s of finding the seller that is the best for them. This establishes 2(i).

A seller will do worse by not joining M. A seller can always pass through the higher cost p_S so as to maintain the same margin as if buyers purchase directly. If a seller deviates and does not join M, the seller will not be recommended by M and so will lose buyers that have joined M. This establishes 2(ii).

The proof of 2(iii) follows the same steps as the proof of (iii) in Proposition 1 except $G(\beta)$ is replaced by $G(s - p_B - p_S)$. The requirement that $p_i^m - p_i^d \leq b(k) - p_B$ no longer applies.

Equilibria in the continuation game in which one seller does not join can be ruled out given such a seller can always do better joining, passing through the extra costs and making some additional profitable sales (as it will be recommended to some buyers that go through M if it joins). The only other equilibrium in the continuation game is the trivial equilibrium. Given the equilibrium selection rule adopted, the equilibrium in 2(i)-2(iii) prevails provided M can obtain a positive profit, which is confirmed below.

In stage one, M sets $p_B \geq 0$ and $p_S \geq 0$ to maximize $(p_B + p_S - k)\, G(s - p_B - p_S)$. The maximization problem is identical to that in the proof of Proposition 1 for a given k and with $b(k)$ replaced by s. Normalizing $p_B = 0$, (5) is the solution for p_S, with $k < p_S < s$, so that M is profitable.

9.12 Proof of Proposition 9

Suppose M sets fees $p_B \geq 0$ and $p_S \geq 0$ in stage 1, with $p_B + p_S > k$ since otherwise M will not make a positive profit. Define $\widetilde{p}_S(p_B) = \frac{2t}{G(s-p_B)}\left(\frac{1}{\sqrt{1-G(s-p_B)}} - 1\right)$ and $\widehat{p}_S(p_B) = \frac{t}{2G(s-p_B)(1-G(s-p_B))}$. Consider buyers' and sellers' equilibrium strategies in stage 2. These are: 2(i) buyers join M if and only if $p_B + c \leq s$ and $p_S \leq \overline{p}_S(p_B)$, where $\overline{p}_S(p_B) = \widetilde{p}_S(p_B)$ if $G(s-p_B)p_S \leq 2t$ and $\overline{p}_S(p_B) = \widehat{p}_S(p_B)$ if $G(s - p_B)p_S > 2t$ (otherwise buyers search and purchase directly); 2(ii) if $p_S \leq \overline{p}_S(p_B)$ then each seller joins M and sets the price $\widehat{p} = d + t + G(s - p_B)p_S$; and 2(iii) if $p_S > \overline{p}_S(p_B)$ then neither seller joins M and each seller prices at $d + t$. Also consider the equilibrium strategies of buyers and M in stage 3. These are: 3(i) buyers that join M follow M's recommendation of which seller to choose; and 3(ii) M recommends each buyer chooses the seller that provides the buyer with the highest net utility from among the sellers that join (if neither seller joins, M randomly selects a seller to recommend to the buyer).

The proof that 3(i)-3(ii) characterize an equilibrium in the stage 3 subgame is identical to the proof in Proposition 8.

To show that 2(i)-2(iii) characterize an equilibrium in the stage 2 subgame, note first that buyers will always complete a purchase. It is easily confirmed that the highest possible price they may face arises when $p_S = \widehat{p}_S(0)$. Then even if they are recommended the seller that involves the maximum possible mismatch, they will still want to purchase given the assumption that $v > d + 2t + \frac{t}{2(1-G(s))}$. Given 2(ii)-2(iii) and 3(ii), buyers pay p_B more if they want to buy through M and incur the cost c

of joining, but avoid the cost s of finding the seller that is the best for them, so 2(i) follows.

Suppose $p_S \leq \overline{p}_S(p_B)$. If both sellers join and set the proposed equilibrium prices, it is straightforward to confirm they will obtain the standard Hotelling profits. Now suppose seller i deviates, does not join M, and sets the price p_i'. Buyers that join M will be recommended the other seller. Seller i's deviation profit is

$$\max_{p_i'}(1 - G(s - p_B))(p_i' - d)\left(\frac{1}{2} + \frac{\widehat{p} - p_i'}{2t}\right),$$

which after substituting in $\widehat{p}$, can be written as

$$(1 - G(s - p_B))(p_i' - d)\left(\frac{1}{2} + \frac{d + t + G(s - p_B)p_S - p_i'}{2t}\right). \tag{12}$$

Provided $G(s - p_B)p_S \leq 2t$, the optimal deviation price is $p_i' = d + t + \frac{G(s-p_B)p_S}{2}$ and substituting this into (12), the corresponding deviation profit is

$$\frac{t}{2}(1 - G(s - p_B))\left(1 + \frac{G(s - p_B)p_S}{2t}\right)^2. \tag{13}$$

Comparing the profit in (13) with the standard Hotelling profit, M will not want to deviate if and only if $p_S \leq \widetilde{p}_S(p_B)$.

In case $G(s - p_B)p_S > 2t$, the optimal deviation price is $p_i' = d + G(s - p_B)p_S$ so that seller i attracts all buyers who purchase directly. Substituting this into (12), the corresponding deviation profit is

$$(1 - G(s - p_B))G(s - p_B)p_S. \tag{14}$$

Comparing the profit in (14) with the standard Hotelling profit, M will not want to deviate if and only if $p_S \leq \widehat{p}_S(p_B)$. This establishes 2(ii).

In case $p_S > \overline{p}_S(p_B)$, the above analysis implies that there is no equilibrium in which both sellers join M. The trivial equilibrium still arises. The standard Hotelling analysis applies, and both sellers price at $d + t$ in equilibrium. This establishes 2(iii).

Regardless of whether $p_S \leq \overline{p}_S(p_B)$ or $p_S > \overline{p}_S(p_B)$, there cannot be any equilibrium in which only one seller joins M. If buyers anticipated that only one seller would join M, buyers would not join M. Buyers would expect that M always recommends the joining seller to any buyers that do join, so buyers would not obtain any additional information from joining. Buyers would always be better of searching directly. Given the equilibrium selection rule adopted, the equilibrium in 2(i)-2(ii) prevails if $p_S \leq \overline{p}_S(p_B)$ provided M obtains a positive profit, which is confirmed below, while the trivial equilibrium is the unique equilibrium if $p_S > \overline{p}_S(p_B)$.

In stage one, M sets $p_B \geq 0$ and $p_S \geq 0$ to maximize the resulting profit $(p_B + p_S - k)\, G\,(s - p_B)$ subject to $p_S \leq \overline{p}_S(p_B)$. Clearly M does best by setting $p_S = \overline{p}_S(p_B)$. Note M can guarantee a positive profit by choosing $p_B = k$. If $p_B = 0$, the remaining properties of the equilibrium outcome stated in the proposition follow by substituting $p_B = 0$ and $p_S = \overline{p}_S(p_B)$ into 2(i)-2(iii). Thus, it remains to show that M does best setting $p_B = 0$ given the assumption that $t > k + \frac{G(s)}{g(s)}$.

Consider the case $G(s - p_B)p_S \leq 2t$. With $p_S = \overline{p}_S(p_B)$, this is equivalent to $G(s - p_B) \leq \frac{3}{4}$. M will choose p_B to maximize $(p_B + \widetilde{p}_S(p_B) - k)G(s - p_B)$. The derivative of this with respect to p_B is always negative if

$$t > (1 - G(s - p_B))^{\frac{3}{2}} \left(\frac{G(s - p_B)}{g(s - p_B)} - (p_B - k) \right). \tag{15}$$

The term in large brackets in (15) is decreasing in p_B due to G being log-concave. Thus, evaluating (15) at $p_B = 0$ and noting that $(1 - G(s - p_B))^{\frac{3}{2}} \leq 1$, $t > k + \frac{G(s)}{g(s)}$ is sufficient to ensure (15) holds. If $G(s - p_B)p_S > 2t$, then $p_S = \overline{p}_S(p_B)$ implies $G(s - p_B) > \frac{3}{4}$ and M will choose p_B to maximize $(p_B + \widehat{p}_S(p_B) - k)G(s - p_B)$. The derivative of this with respect to p_B is always negative if

$$t > 2\,(1 - G(s - p_B))^2 \left(\frac{G(s - p_B)}{g(s - p_B)} - (p_B - k) \right). \tag{16}$$

However, given $G(s - p_B) > \frac{3}{4}$, if (15) holds then so does (16). Suppose $G(c) = \left(\frac{c}{\overline{c}}\right)^{\alpha}$. Then $\frac{G(s)}{g(s)} = \frac{s}{\alpha}$, and (15) becomes $t > k + \frac{s}{\alpha}$. Given our assumptions that $\frac{t}{4} > s$ and $s > k$, this holds provided $\alpha > \frac{1}{3}$.

9.13 Proof of Proposition 10

From Proposition 9, M's profit in case it imposes price coherence is $\max_{p_B \geq 0} (p_B + \overline{p}_S(p_B) - k)\, G\,(s - p_B)$. From Proposition 8, M's profit in case it does not impose price coherence is $\max_{p_S \geq 0} (p_S - k)\, G\,(s - p_S)$. Since $\overline{p}_S(p_B) > 0$ for any $G\,(s - p_B) > 0$, clearly M will want to impose price coherence. The first-best solution requires all buyers with $c \leq s - k$ should join M. In the equilibrium in Proposition 8, buyers join M if and only if $c \leq s - p_S^*$. Since $p_S^* > k$, too few buyers join M without price coherence. In the equilibrium in Proposition 9, buyers join M if and only if $c \leq s$. Thus, too many buyers join M with price coherence.

The consumer surplus generated by M is positive without price coherence since each buyer that joins M obtains a positive surplus due to the existence of M, while those that do not join can buy at $d+t$ and so are unaffected. With price coherence, $G(s)$ buyers join and save search costs $\int_0^s (s-c)dG(c)$. All buyers pay $G(s)\overline{p}_S(0)$ more. If $G(s) \leq \frac{3}{4}$, M's contribution to consumer surplus is $G(s)\left(s - E[c|c<s] - \widetilde{p}_S(0)\right)$, which is negative given $\frac{t}{4} > s$. Similarly, if $G(s) > \frac{3}{4}$, M's contribution to consumer surplus is $G(s)\left(s - E[c|c<s] - \widehat{p}_S(0)\right)$, which is negative given $\frac{t}{4} > s$. Note that M lowers consumer surplus holds even ignoring the buyers' average costs of joining $G(s)E[c|c<s]$.

9.14 Proof of Proposition 11

Without price coherence, the contribution to welfare must be positive since $p_S^* > k$, which is passed through to buyers, so buyers only join when they contribute positively to welfare. Suppose $G(c) = \left(\frac{c}{\overline{c}}\right)^{\alpha}$. With price coherence, the welfare contribution of M is $\int_0^s \left(\alpha c^{\alpha-1}\frac{s-c-k}{\overline{c}^{\alpha}}\right)dc = \frac{s^{\alpha}}{(1+\alpha)\overline{c}^{\alpha}}\left(s-(1+\alpha)k\right)$, which is negative if and only if $k > \frac{s}{1+\alpha}$.

A Online appendix: Markets with price coherence

This supplementary appendix extends the discussion of selected markets with price coherence, providing references and additional detail. It also discusses other markets with price coherence beyond those examined in the main paper, specifically real estate buyers' agents as well as restaurant reservations and ordering.

A.1 Travel booking networks

Since airlines are aligned in seeking lower fees from GDSs, they might be expected to engage in some form of coordination to constrain GDS fees. But airlines and GDSs have long-term contracts, typically five years, and the contract expirations are now staggered. As a result, each airline negotiates with GDSs individually, taking as given the long-term contracts of other airlines.

Numerous airlines have questioned and criticized rising GDS costs. American Airlines was the first to take forceful action: In 2009, it began to offer "direct connect" which allowed to let large travel agents connect their systems directly to American's servers, bypassing a GDS. But implementing this approach required significant changes to travel agent systems, and some GDSs disabled key technologies that let a travel agent compare direct connect flights with GDS flights. (Schaal, 2011) Furthermore, GDS incentives often required a travel agent to sell a particular quantity of tickets in order to earn full payment from a GDS, a payment structure which discouraged travel agents from switching to a lower-cost channel such as direct connect. Finally, it was unclear what incentives American was offering to travel agencies that switched to direct connect. To make direct connect more attractive than a GDS, American would need to pay more than what the GDS was offering travel agents, but any such payment would be hard to reconcile with American's efforts to reduce distribution cost.

In 2011, news reports indicated that the U.S. Department of Justice was concerned about the market for airline reservation systems (Boehmer, 2011), but the DOJ has not yet filed a case in this area. Meanwhile, American Airlines in 2011 filed private antitrust litigation against one GDS, SABRE, alleging demotion of American's flights in SABRE's systems, which made AA's flights more difficult to find or, in some cases, completely unavailable. American claimed that SABRE took these actions in response to American's implementation of direct connect. (American Airlines Inc. v. Sabre Inc., 2010) The case settled in 2012, with SABRE agreeing to discontinue penalizing or hiding American's flights and agreeing to pay American $280 million. Even after the settlement, American's direct connect continued to struggle to attract travel agents.

Booking networks for hotel rooms and car rentals raise many of the same issues. Historically, norm and sometimes contract constrained car and hotel prices to be equal whether a consumer booked directly or via a reservation system. However, hotel and car providers now offer lower prices through non-GDS channels, particularly for low-flexibility offerings (e.g. prepaid bookings). Despite GDSs willingness to forego price coherence for hotel rooms and car rentals, many online travel agencies impose similar requirements. For example, Booking.com requires hotels to provide rate "parity" including "the same or better rates for the same accommodation, ... dates, ... and cancellation policy" that the hotel offers directly or via any other booking agency. (Booking.com, 2012)

Department of Transportation (2004) provides details about the GDS market and prevailing practices and fees.

A.2 Credit and debit cards

Mannix (1994) reviews the early history of credit cards, including the rise of cashback cards. Akers *et al.* (2005) examines payment flow within card networks, interchange fees, and the resulting incentives. Prager *et al.* (2009) and Rysman and Wright (2012) present relevant institutions, incentives, and implications. In this section, we add references to support the factual claims in Section 2.2 and relate our contributions to the relevant economics literature.

In ten U.S. states, laws disallow credit card surcharges. (Visa, 2013) Visa and Mastercard used contracts to impose similar rules. That said, litigation and regulation have ended this restriction in some countries. For example, U.S. litigation required Visa and Mastercard to allow merchants to impose credit surcharges if they so choose, beginning in January 2013 (except where prohibited by state law). (In Re Payment Card Interchange Fee and Merchant Discount Litigation - Class Settlement Agreement, 2012)

In 1986, Discover began to offer a 1% rebate card (Discover Bank, 2013), and multiple Visa issuers added a similar benefit in 1994 (Mahoney, 1994). Greater rebates became available later, including multiple U.S. cards with comprehensive 2% rebates. Via payment cards' multi-party network structure, funding for these rebates ultimately comes from the fees paid by merchants. (Akers *et al.*, 2005)

Numerous critics have that alleged that interchange fees are too high and promote the over-usage of cards. Examples include the Reserve Bank of Australia, the European Commission, and the United States Government Accountability Office, as well as a number of economists (e.g. Carlton and Frankel (1995); Katz (2001); Cabral (2006); Vickers (2005); Farrell (2006)).

The theoretical literature on payment cards has focused on showing conditions under which sellers are charged too much and cardholders too little for card transactions, resulting in excessive card usage. See, for example, (Rochet and Tirole, 2002; Wright, 2004; Guthrie and Wright, 2007; Rochet and Tirole, 2011; Wright, 2012; Bedre-Defolie and Calvano, 2013). Our results are stronger than the findings of these previous works: We demonstrate the possibility that consumer surplus and welfare are actually lowered by the existence of a card system. We also explore the welfare implications of imposing price coherence, an issue which has only previously been considered in Wright (2003) and Schwartz and Vincent (2006), settings in which merchant internalization was assumed away. Finally, our results occur in a simpler and more generic setting. In particular, we do not require that there are different sectors of sellers, each drawing different benefits of accepting cards, or separate issuers and acquirers, as assumed in Bedre-Defolie and Calvano (2013) and Wright (2012).

A.3 Insurance brokers and financial advisors

Regulators have sought to reshape insurance and financial advising commissions due to concerns about biased recommendations—brokers and advisors promoting certain services and investments based on commission rather than consumers' needs. Regulators also identified the problem of intermediaries causing increased costs, including forcing consumers to pay for full-service brokers and advisors that they may not need.

The U.S. market for title insurance prompted scrutiny from regulators due to an exceptionally large gap between premiums and losses. In 2007, the GAO reported that just 5% of title insurance premiums went to cover losses, compared with 73% of premiums for casualty insurance. In contrast, the GAO found that 70% of title insurance premiums were paid to or retained by title agents. (GAO (2007), p.41) Spending so little on claims suggests a premium far above the actuarially fair rate.

Examining the cause of high prices for title insurance, the GAO noted that title insurance vendors are largely chosen not by buyers of real estate but by real estate professionals, attorneys, and title agents who facilitate transactions. (GAO (2007)) To attract referrals, underwriters pay large commissions and incentives. With some restrictions, underwriters are permitted to pay fees to the attorneys and title examiners who issue title insurance. That said, under federal law and many state laws, these payments must be bona fide compensation for services actually performed, not mere commissions or referral fees. (See RESPA 12 USC 2607(a),(c).) But Hunter (2006) found that these fees totaled 77.5% to 82% of the price of title insurance—charges difficult to reconcile with the number of hours of work or the level of skill required. Meanwhile, numerous investigations found impermissible payments. For example, a 2006 investigation by the Washington State Office of the Insurance Commissioner found unlaful payments "widespread and pervasive," including payments to builders, real estate professionals, and lenders. (Kreidler, 2006) At the time, common Washington incentives included gift cards, meals, and tickets to sporting events. Hunter (2006) found that one title insurance underwriter spent 4% of operating expenses on settlements and litigation costs resulting from disputed payments and incentives, more than triple the amount that the underwriter spent on paying claims.

More recently, several countries' regulators sought to reshape sales practices for various financial services as well as life insurance. Effective December 31, 2012, the UK prohibited advisors from receiving commission for their advice (as to multiple financial services including life insurance). Advisors could deduct their charges from a client's investment, or could charge on a fixed rate, hourly rate, or in some other way, but advisors' fees had to be disclosed to investors separately. The rules are embodied in the Amendments to the Conduct of Business Sourcebook (COBS) (2010). In subsequent reminders to financial services firms and advisors, the UK Financial Services Authority specifically reaffirmed the ban on commissions and noted that it is prohibited to attempt to "work around" that ban. (Financial Services Authority, 2012)

Effective July 1, 2013, Australia banned "conflicted remuneration" from financial services firms to advisors. The ban ended commissions as well as "soft" benefits, as to sales of financial services as well as life insurance. Important exceptions apply, including payments pursuant to contracts established before the new rules took effect, as well as exemptions allowing commissions on certain "basic" banking products. The new rules are embodied in the Australian Corporations Amendment (Future of Financial Advice) Act (2012), and a Frequently Asked Questions web page clarifies key provisions.

In a 2013 consultation paper (Monetary Authority of Singapore, 2013) and response (2013b), the Monetary Authority of Singapore (MAS) evaluated and implemented new requirements for financial advisors. The resulting rules allow financial services firms to pay commissions to advisors but prohibit inducing advisors with "additional cash or non-cash incentives ... over and above the typical commissions ... which are tied to the sales volume of investment products." The stated rationale for this prohibition was that such incentives encourage advisors to direct customers to unsuitable investment products, but the prohibition also requires that all products have exactly the "typical" commission rate, which tends to reinforce price coherence. That said, MAS also took steps to facilitate use of low-cost channels: After noting that prevailing pricing practices offer no savings to self-directed customers who buy insurance from a low-cost distribution channel, MAS required that certain "basic" life insurance be available through direct online sales, bypassing brokers and advisors. These changes are slated to take effect in January 2015.

A broader set of inquiries—by diverse regulators, consumer advocates, and journalists—examine insurance sales practices more generally. For example, Robertson and Perkins (2010) review insurance commissions in Canada, and Kollmorgen (2013) looks at various insurance rebates in Australia. GAO (2007) examines title insurance in the U.S., while Kreidler (2006) studies title insurance in Washington State in greater detail, and Health Now Administrative Services - HNAS (2013) tabulates U.S. state restrictions on insurance rebates. Eagle Insurance Brokers (2011) and Robertson and Perkins (2010) consider the perspective of insurance brokers and the resulting incentives for insurers.

A.4 Marketplaces

More than 2 million independent sellers offer products at Amazon Marketplace. (Steiner, 2013)

In February 2013, the Bundeskartellamt (the German competition regulator) opened an investigation of Amazon's "general pricing policy," which requires that sellers offer prices in Amazon Marketplace at or below their prices in other online sales channels. The Bundeskartellamt suggested that the policy could allow Amazon to charge higher fees to sellers, yielding higher prices to consumers without offsetting benefits. (Bundeskartellamt, 2013) In response to this and other scrutiny from European regulators, in August 2013 Amazon removed its general pricing policy from its Marketplace contracts in the European Union. The rule remains in effect everywhere else.

A.5 Search engine advertising

Another factor constraining prices to be equal, whether or not a user reaches a merchant from a search engine advertisement, is that consumers have objected to other instances in which merchants offered different prices or products based on factors that users did not anticipate. See user response to merchants' random experiments (Wolverton, 2000), computer configuration (Mattioli, 2012), and user location and nearby competition (Valentino-Devries *et al.*, 2012). Presenting different prices to search engine users would likely prompt similar backlash.

For differences in advertising prices across search engines, see Hamilton (2013).

A.6 Real estate buyers' agents

In most of the U.S. and Canada, *buyer's agents* assist prospective real estate buyers. Buyers' agents often identify properties of possible interest, arrange in-person visits, and assist with submitting an offer. In principle, buyers could pay for these services directly. Instead, *sellers* typically pay buyers' agents at a rate specified in each property's entry in the Multiple Listing Service or other database of available properties. In 2012, 59% of U.S. home-buyers were represented by buyers' agents. Buyer's agents fees were typically 2.5% to 3%, half of the 5% to 6% charged by real estate agents on each transaction.

Because buyers do not pay buyers' agents directly, buyers often perceive that these services are "free." If a buyer's agent truly entails no incremental cost to the buyer, a rational buyer would use the services if their gross value is even slightly positive.

A shrewd buyer might realize that a seller pays for the services of a buyer's agent. Such a buyer might forego the services of a buyer's agent to provide a savings to the seller and ask the seller to accept a lower selling price. But market structure impedes this approach. For one, when a seller hires a seller's agent to market a property, the standard contract calls for the seller to pay a flat percentage (say, 5%) to the seller's agent. Thus, if the buyer forgoes a buyer's agent, the seller's agent retains the full 5%, and the buyer and seller get none of the savings. A shrewd seller might attempt to negotiate a revision of this term when initially retaining a seller's agent. But seller's agents largely refuse such a change, citing state law and/or office policy. Since most buyers use buyer's agents, sellers have little incentive to press the point.

The prevailing market structure impedes competition that might reduce fees to buyer's agents. A concerned seller could offer lower compensation to buyers' agents—perhaps 2% in a market where 2.5% is standard. But consider the consequence: Having built a relationship with an intending buyer likely to buy *some* property, and having perhaps signed an exclusive representation agreement with that buyer, a buyer's agent has little incentive to feature a property with a lower commission. Rather, the buyer's agent receives a larger fee by directing the buyer to one of the many properties with the market-standard fee to a buyer's agent. A seller offering a reduced buyer's agent commission thus risks fewer buyers, a slower sale, and a lower selling price. Competition among buyers' agents does not fix the problem: Buyers' agents compete for available buyers (perhaps offering superior service), but the market structure gives them neither incentive nor ability to lower the fees charged to sellers.

Some buyers and sellers circumvent this market structure, often attaching ad hoc amendments to contracts or offers. But these transactions are unusual, requiring specialized information and skill.

The US Department of Justice in 2005 filed a Sherman Act antitrust complaint alleging that real estate agents reduced competition on price and quality, raised barriers to entry, and impeded the efforts of limited-service brokers who offer reduced and a-la-carte services at a lower fee. (United States of America v. National Association of Realtors, 2005) In a 2008 final judgment, the National Association of Realtors agreed to cooperate with limited-service brokers. (United States of America v. National Association of Realtors, 2008) A limited-service seller's agent lets a seller submit a property to a regional property listing database without paying a full seller's agent's fee. (A seller can then pay fee-for-service for assistance taking photos, running open houses, and receiving offers, or a seller can do these tasks without professional assistance.) Similarly, if a buyer chooses a limited-service buyer's agent, the buyer's agent rebates to the buyer a portion of the fees received from the seller, somewhat reducing the net cost of the institution of buyer's agents for that transaction.

Despite the availability of limited-service buyer's agents, the overall market structure remains. In principle a buyer can shift from a full-service buyer's agent to a limited-service buyer's agent, collecting approximately a 1% rebate. But even a buyer who engages a limited-service buyer's agent still pays approximately 1% of the home's purchase price to that buyer's agent—a large expense difficult to reconcile with the hours worked. A buyer who prefers to forego buyer's agent services still has no easy or standard way to realize the full savings of that choice.

Ten U.S. states prohibit brokers from offering cash rebates to consumers. The Department of Justice has investigated these restrictions and encouraged state legislatures to end these prohibitions. (Department of Justice (DOJ) - Antitrust Division, 2011) The DOJ quotes a real estate agent: "If we give rebates and inducements, it would get out of control and all clients would be wanting something. The present law keeps it under control." While agents benefit from this prohibition, DOJ argues that agents' benefit comes directly from increased fees to consumers.

National Association of Realtors (NAR) (2012) surveys home-buyers about their use of buyers' agents (among other factors), while Adams (2008) tracks agents' fees. Greater Boston Real Estate Board (GBREB) (2005) presents a standard contract for a home seller to retain a seller's agent, including no reduction in fee if the buyer does not use a buyer's agent.

A.7 Restaurant ordering services

Online restaurant ordering services present menus for a variety of participating food providers, letting buyers choose their restaurant and dishes, specify a place for delivery or time for pickup, and even tender payment online. The ordering service transmits the order to the restaurant, often by fax. The ordering service typically charges the customer's credit card, then provides periodic payment to each restaurant.

From a buyer's perspective, online ordering can be more convenient than ordering by telephone. Consider complex orders (Goldfarb *et al.*, 2012), users without a printed copy of a restaurant's menu, and users who value electronic receipts and order histories.

For restaurants, an online ordering service offers a mix of internal and external benefits. Online ordering can improve restaurant operations, including avoiding errors and reducing staff time spent on telephone orders. Online ordering is also valued by customers, and it could reach customers who would not otherwise know about a restaurant. Indeed, online ordering services typically emphasize attracting new customers. For example, Foodler promises to bring "additional business."

Prices are usually identical for ordering services versus ordering directly from the same restaurant (e.g. by telephone). For example, Seamless explains that "restaurants are contractually required to offer the same prices as they provide on their printed delivery menus." When litigation alleged that some restaurants posted higher prices to GrubHub than they charged customers who ordered directly, GrubHub called this a mistake but agreed that it was improper. Ordering services position price coherence as a benefit to consumers—a guarantee that using an ordering service, rather than ordering directly, does not increase a customer's cost.

Rather than collecting a surcharge from consumers, ordering services deduct a portion of each order from the restaurant. Ordering services typically do not disclose their fees publicly, but news reports suggest fees of approximately 15%. (Shank, 2004)

With prices constrained to be equal between direct purchases and online ordering services, online ordering services cannot compete with each other by lowering their posted prices. Instead, ordering services establish incentives to spur consumers' usage. For example, GrubHub offers periodic large discounts (regularly as much as 20% off for an order of a specific size in a brief time period). At Foodler, each order earns points redeemable for discounts.

Although online ordering services have been available for more than a decade, the market remains in flux, and it may be premature to attempt to characterize long-term market structure. But online ordering service fees to restaurants have already risen—starting at 10% to 12%, but now reportedly as large as 18%. Meanwhile, there were initially no consumer rebate/points programs, but such programs are now relatively standard. To date, points and rebates remains modest—approximately 1% at Foodler—but an upward trend is clear. Moreover, price coherence creates a natural context for competition through points and rebates.

Note that the absence of fees (to consumers) for restaurant *ordering* contrasts with the often differing prices that exist for dine-in versus takeout and delivery. It is common for prices to differ across dining formats: few U.S. consumers offer gratuities for takeout orders (reducing the gross price of takeout relative to dine-in); many U.S. restaurants provide takeout-only coupons; UK restaurants often offer standard takeout discounts; and Singaporean food court vendors charge extra for takeout containers.

A.8 Restaurant reservation services

In addition to fees for online ordering services, restaurants also pay for online reservation systems. In the U.S., the best-known reservation system is OpenTable, which charges restaurants $1 per person in each honored reservation plus $199 per month and a setup fee of approximately $1,000. (OpenTable, 2010) Restaurants do not offset these expenses with any special charge to diners—no "reservation fee" collected from the customers who use reservation services. Diners would surely view an itemized reservation fee as improper since it is an unwanted expense for a service that diners expect to be included. Nor could restaurants plausibly present different menus to customers who use reservation services—consumers and regulators would complain when the practice was discovered, and any restaurant using this strategy would probably be ejected from the reservation service.

With price constrained to be equal whether or not a diner uses a reservation service, reservation services seek to attract extra diners. Of course diners need no special encouragement to make reservations for popular restaurants at peak hours. But reservation services also encourage diners to make reservations even when diners correctly anticipate that restaurants have plenty of capacity. For example, OpenTable Dining Rewards Points pay a diner for each honored reservation; after twenty reservations, a diner can claim a $20 discount valid at any OpenTable restaurant. As of June 30, 2013, OpenTable reports $32 million of Dining Rewards outstanding, approximately 40% of OpenTable's liabilities. (OpenTable, 2013) Assuming an average party of three, if Dining Rewards were used by all diners, this rebate would reduce OpenTable's net fees by one third.

Other restaurant reservation services offer similar benefits to diners. For example, Hong Kong-based TableMap offers gifts and vouchers after a user makes and uses two or more reservations. TableMap's rebates offer users a net value of 10 HKD (approximately US $1.30) per reservation. TableMap (2013)

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B Online appendix supplementing proof of Proposition 2

The proof of Proposition 2 established the existence of a symmetric equilibrium in which both sellers join M. In this supplementary appendix, we rule out an asymmetric equilibrium in which one seller joins M and the other does not. We show such an asymmetric equilibrium does not arise in any continuation game starting from stage 2.

Suppose M imposes price coherence, sets fees $p_B \geq 0$ and $p_S \geq 0$, and chooses investment $k \geq 0$ in stage 1. For brevity define $b \equiv b(k)$. Note that $b > p_B$; otherwise, no buyer would ever join and use the intermediary. Define $\beta = b - p_B - p_S$. Suppose there exists an asymmetric equilibrium in the stage 2 subgame in which seller 1 joins M while seller 2 does not join M. Suppose a mass of $0 < G < 1$ buyers join M. (If $G = 0$, there cannot be any asymmetric equilibrium, while the case with $G = 1$ will be considered later). Thus, seller 1's problem is to choose p_1 to maximize

$$\pi_1 = (1 - G)(p_1 - d)s_d + G(p_1 - d - p_S)s_m,$$

where

$$s_d = \frac{1}{2} + \frac{p_2 - p_1}{2t}$$

and

$$s_m = \frac{1}{2} + \frac{b - p_B + p_2 - p_1}{2t},$$

while seller 2's problem is to set p_2 to maximize

$$\pi_2 = (1 - G)(p_2 - d)\left(1 - s_d\right) + G(p_2 - d)\left(1 - s_m\right).$$

Consider the possible cases which depend on whether the proposed equilibrium involves an interior solution or a corner solution. Given $b - p_B > 0$, clearly $s_m > s_d$ and so $1 - s_d > 1 - s_m$. There are four cases: (1) an interior solution where $0 < s_d < 1$ and $0 < s_m < 1$; (2) a corner solution where $0 < s_d < 1$ and $s_m = 1$; (3) a corner solution where $s_d = 0$ and $0 < s_m < 1$; and (4) a corner solution where $s_d = 0$ and $s_m = 1$.

Interior solution

Suppose an interior solution exists. The proposed equilibrium prices are

$$\begin{aligned} p_1 &= d + t + Gp_S + \frac{G\beta}{3} \\ p_2 &= d + t - \frac{G\beta}{3}. \end{aligned}$$

The market shares for seller 1 are

$$\begin{aligned} s_d &= \frac{1}{2t}\left(t - Gp_S - \frac{2G\beta}{3}\right) = \frac{1}{2t}\left(t - \frac{2G\left(b - p_B\right)}{3} - \frac{Gp_S}{3}\right) \\ s_m &= \frac{1}{2t}\left(t + \beta + \left(1 - G\right)p_S - \frac{2G\beta}{3}\right) = \frac{1}{2t}\left(t + b - p_B - \frac{2G\left(b - p_B\right)}{3} - \frac{Gp_S}{3}\right). \end{aligned}$$

Given $b - p_B > 0$ and $p_S \geq 0$, clearly $s_d < \frac{1}{2}$. Also, since $s_m > s_d$, a sufficient condition for the interior solution is $s_d > 0$ and $s_m < 1$. This requires

$$3t > 2G\left(b - p_B\right) + Gp_S \tag{17}$$

$$3t > \left(3 - 2G\right)\left(b - p_B\right) - Gp_S. \tag{18}$$

Now suppose $\beta \geq 0$. This implies $p_B + p_S \leq b\left(k\right)$, so at most M can recover $b(k)$ in the fees to buyers and sellers. Thus, when $\beta \geq 0$, consider $k \leq \overline{k}$ since any higher k implies that M makes a loss. It follows from $t > b(\overline{k})$ that $t > b - p_B$ and $t > p_S$, which imply (17) and (18) hold. At this interior solution, the profits of the sellers are

$$\pi_1 = \left(\frac{1-G}{2t}\right)\left(t+Gp_S+\frac{G\beta}{3}\right)\left(t-Gp_S-\frac{2G\beta}{3}\right) + \frac{G}{2t}\left(t-(1-G)p_S+\frac{G\beta}{3}\right)\left(t+\beta+(1-G)p_S-\frac{2G\beta}{3}\right) \tag{19}$$

$$\pi_2 = \left(\frac{1-G}{2t}\right)\left(t-\frac{G\beta}{3}\right)\left(t+Gp_S+\frac{2G\beta}{3}\right) + \frac{G}{2t}\left(t-\frac{G\beta}{3}\right)\left(t-\beta-(1-G)p_S+\frac{2G\beta}{3}\right). \tag{20}$$

In the special case that $\beta = 0$, then

$$\pi_1 = \frac{t}{2} - \frac{G(1-G)}{2t}p_S^2$$

and seller 1 can clearly do strictly better not joining M, setting the same price as seller 2 ($p_1' = d + t$) so that its market share will be one half, and obtaining the standard Hotelling profit. (This result uses that $p_S > 0$, which follows since $\beta = b - p_B - p_S = 0$ and $b > p_B$.) So the proposed equilibrium is not in fact an equilibrium when $\beta = 0$.

In case $\beta > 0$, seller 2 can do better deviating, joining M, and setting the same price as seller 1, so that its market share will be one half. Its deviation profit will be

$$\pi_2' = \frac{t}{2} + \frac{G\beta}{6}$$

which will increase its profit by

$$\frac{\beta G(9t - G\beta)}{18t}.$$

This is positive given $t > b \geq \beta$. So the proposed equilibrium is not in fact an equilibrium when $\beta > 0$.

Suppose instead that $\beta < 0$ but the proposed equilibrium remains defined by the interior solution above. Since $p_B + p_S \leq b(k)$ no longer holds, $k > \overline{k}$ becomes possible, and the condition $t > b(\overline{k})$ cannot be used. Consider seller 1 deviating by not joining M and setting the same price as seller 2, so that its market share will be one half. Its deviation profit is

$$\pi_1' = \frac{t}{2} - \frac{G\beta}{6}$$

which increases its profit by

$$\frac{G}{18t}\left(9\left(1-G\right)\left(b-p_B\right)-9t\beta-G\beta^2\right).$$

Using (17), this deviation profit exceeds

$$\frac{G}{18t}\left(9\left(1-G\right)\left(b-p_B\right)-6G\left(b-p_B\right)\beta-3G\beta p_S-G\beta^2\right).$$

Replacing $G\beta^2$ with $G\beta\left(b-p_B-p_S\right)$ and collecting terms, the deviation profit exceeds

$$\frac{G}{18t}\left(9\left(1-G\right)\left(b-p_B\right)-7G\left(b-p_B\right)\beta-2G\beta p_S\right),$$

which is positive since $\beta<0$ and $b>p_B$. So the proposed equilibrium is not in fact an equilibrium when market shares are interior and $\beta<0$.

In summary, there is no asymmetric equilibrium which involves each seller selling to both types of buyers.

Corner solution 1

Consider a proposed equilibrium involving a corner solution, whereby $0<s_d<1$, $s_m=1$ and $\beta<0$. Then

$$\begin{aligned}\pi_1 &= (1-G)\left(p_1-d\right)\left(\frac{1}{2}+\frac{p_2-p_1}{2t}\right)+G(p_1-d-p_S)\\ \pi_2 &= (1-G)(p_2-d)\left(\frac{1}{2}+\frac{p_1-p_2}{2t}\right).\end{aligned}$$

The proposed equilibrium prices that support this corner solution are

$$\begin{aligned}p_1 &= d+t+\frac{4Gt}{3(1-G)}\\ p_2 &= d+t+\frac{2Gt}{3(1-G)}.\end{aligned}$$

For the proposed equilibrium to hold, it must be that $s_m=1$, so this requires

$$p_S+\beta>\frac{(3-G)\,t}{3\,(1-G)}$$

and since $\beta < 0$ this requires

$$p_S > \frac{(3-G)\,t}{3\,(1-G)}. \tag{21}$$

Seller 1's profit in the proposed equilibrium is

$$\pi_1 = \frac{t\,(3+G)\,(3-5G)}{18\,(1-G)} + G\left(t + \frac{4Gt}{3\,(1-G)} - p_S\right) \tag{22}$$

Now suppose seller 1 deviates by not joining M and by setting the same price as seller 2, so its market share is one half. Its deviation profit is

$$\pi_1' = \frac{t}{2} + \frac{Gt}{3(1-G)},$$

which increases its profit by

$$Gp_S - \frac{Gt\,(9+G)}{18\,(1-G)}.$$

Using (21), this is always positive.

Thus, there is no asymmetric equilibrium involving the corner solution defined by $0 < s_d < 1$ and $s_m = 1$.

Corner solution 2

Consider a proposed equilibrium involving a corner solution, whereby $s_d = 0$, $0 < s_m < 1$ and $\beta < 0$. Then

$$\begin{aligned}
\pi_1 &= G\,(p_1 - d - p_S)\left(\frac{1}{2} + \frac{b - p_B + p_2 - p_1}{2t}\right) \\
\pi_2 &= (1-G)\,(p_2 - d) + G\,(p_2 - d)\left(\frac{1}{2} + \frac{p_B - b + p_1 - p_2}{2t}\right).
\end{aligned}$$

The proposed equilibrium prices that support this corner solution are

$$\begin{aligned}
p_1 &= \frac{1}{3G}\,(2t + Gt + G\beta + 3Gd + 3Gp_S) \\
p_2 &= \frac{1}{3G}\,(4t - Gt - G\beta + 3Gd)\,.
\end{aligned}$$

For the proposed equilibrium to hold, it must be that seller 1 attracts some buyers through M, which requires

$$2t + G\beta + Gt > 0. \tag{23}$$

Seller 1's profit in the proposed equilibrium is

$$\pi_1 = \frac{(2t + G\beta + Gt)^2}{18Gt}. \tag{24}$$

Now suppose seller 1 deviates by not joining M and sets p_1' to maximize its profit

$$(p_1' - d)\left(\frac{1}{2} + \frac{p_2 - p_1'}{2t}\right).$$

Given the proposed equilibrium price p_2, this implies

$$p_1' = \frac{4t - G\beta + 6Gd + 2Gt}{6G}$$

implying a deviation profit of

$$\pi_1' = \frac{(4t - G\beta + 2Gt)^2}{72G^2 t}. \tag{25}$$

Note seller 1's market share in the deviaton is

$$\frac{4t + 2Gt - G\beta}{12Gt},$$

which is positive. This exceeds one if

$$4t - 10Gt - G\beta > 0, \tag{26}$$

in which case the deviation price would instead be

$$p_1' = d + \frac{1}{3G}(4t - G\beta - 4Gt)$$

and the deviation profit would instead be

$$\pi_1' = \frac{4t - G\beta - 4Gt}{3G}. \tag{27}$$

Comparing (25) with (24), seller 1 is better off deviating since

$$\frac{(4t - G\beta + 2Gt)^2}{72G^2 t} = \frac{1}{18G^2 t}\left(2t - \frac{G\beta}{2} + Gt\right)^2 > \frac{(2t + G\beta + Gt)^2}{18Gt}$$

with the inequality holding given $\beta < 0$. The profit in (27) can be rewritten as

$$\pi_1' = 3t\frac{(8t - 2G\beta - 8Gt)}{18Gt} > (2t + G\beta + Gt)\frac{(8t - 2G\beta - 8Gt)}{18Gt}, \tag{28}$$

since $(1-G)\,t > G\beta$ as $\beta < 0$. Comparing the right hand side of (28) with (24), the deviation profit is higher if

$$8t - 2G\beta - 8Gt > 2t + G\beta + Gt$$

or in other words if

$$6t - 9Gt - 3G\beta > 0. \tag{29}$$

Summing up (23) and (26) yields

$$G < \frac{2}{3},$$

which together with $\beta < 0$ ensure that (29) holds.

Thus, there is no asymmetric equilibrium involving the corner solution defined by $s_d = 0$ and $0 < s_m < 1$.

Corner solution 3

Consider a proposed equilibrium involving a corner solution, whereby $s_d = 0$, $s_m = 1$ and $\beta < 0$. Then

$$\begin{aligned} \pi_1 &= G(p_1 - d - p_S) \\ \pi_2 &= (1-G)(p_2 - d). \end{aligned}$$

The proposed equilibrium prices that support this corner solution must satisfy

$$\frac{1}{2} + \frac{p_2 - p_1}{2t} \leq 0$$

and

$$\frac{1}{2} + \frac{p_1 - p_2 + p_B - b}{2t} \leq 0.$$

These constraints must be satisfied with equality since otherwise one of the sellers can do better by raising its price without losing any buyers to the other seller. Thus,

$$\begin{aligned} t + p_2 - p_1 &= 0 \\ t + p_B - b + p_1 - p_2 &= 0. \end{aligned}$$

These equalities cannot both hold unless $2t = b - p_B$. Given $\beta < 0$, this implies $p_S > 2t$. In the proposed equilibrium, this requires $p_1 > d + p_S$ and thus $p_1 > d + 2t$.

Now consider a possible deviation by seller 1 in which it deviates by not joining M and setting a price $p_1' = p_2 - t$. Seller 1 captures the entire market from both groups of consumers. Its deviation profit is

$$\pi_1' = (1 - G)(p_1' - d) + G(p_1' - d).$$

Using $p_1' = p_2 - t$ and $t + p_2 - p_1 = 0$, rewrite the deviation profit as

$$\pi_1' = (1 - G)(p_1 - 2t - d) + G(p_1 - 2t - d).$$

This increases the proposed equilibrium profit by

$$(1 - G)(p_1 - 2t - d) + G(p_S - 2t),$$

which is clearly positive given $p_1 > 2t + d$ and $p_S > 2t$. Thus, there is no asymmetric equilibrium involving the corner solution defined by $s_d = 0$ and $s_m = 1$.

The case in which all buyers join the intermediary

Suppose $G = 1$. This case is only relevant if $\beta < 0$. If $\beta \geq 0$, then $p_S \leq b(k)$ so M sets $k \leq \overline{k}$ given any higher k implies it makes a loss. Therefore buyers at most expect to get a surplus of $b\left(\overline{k}\right)$ from joining M, and so not all buyers join given our assumption that $\overline{c} > b\left(\overline{k}\right)$.

Assume there exists an asymmetric equilibrium in which seller 1 joins M while seller 2 does not join M. Thus seller 1's problem is to choose p_1 to maximize

$$(p_1 - d - p_S)\left(\frac{1}{2} + \frac{b - p_B + p_2 - p_1}{2t}\right)$$

while seller 2 chooses p_2 to maximize

$$(p_2 - d)\left(\frac{1}{2} + \frac{p_B - b + p_1 - p_2}{2t}\right).$$

The proposed equilibrium prices are

$$\begin{aligned} p_1 &= d + t + p_S + \frac{\beta}{3} \\ p_2 &= d + t - \frac{\beta}{3}. \end{aligned}$$

A condition for these prices to lead to an interior solution is $3t > \beta > -3t$. Thus, the proposed equilibrium profits are

$$\begin{aligned} \pi_1 &= \frac{1}{2t}\left(t + \frac{\beta}{3}\right)^2 \\ \pi_2 &= \frac{1}{2}\left(t - \frac{\beta}{3}\right)^2. \end{aligned}$$

Given $\beta < 0$, seller 1 is strictly better off by not joining M and setting the same price as seller 2, so that its market share will be one half, and obtaining a profit that exceeds the standard Hotelling profit. Thus, there is no asymmetric equilibrium if $G = 1$.