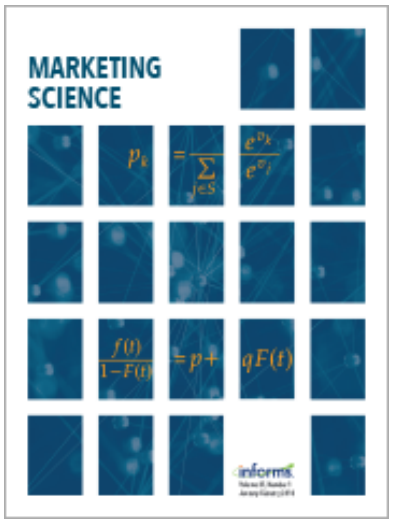

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Exclusive Handset Arrangements in the Wireless Industry: A Competitive Analysis

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In many markets, a handset vendor and a service provider may enter into a tie-in for a handset to be available exclusively through the service provider. We examine when and why a service provider and a handset vendor may find this arrangement mutually profitable. We find that an exclusive handset arrangement (EHA) may serve a dual strategic purpose. By restricting its handsets to one service provider, a handset vendor may be able to induce a rival handset vendor to compete less aggressively. At the same time, the service provider may be able to essentially raise a rival service provider's handset costs by limiting the handsets available to the rival. Interestingly, the handset vendor's market share may be higher when its handset is sold exclusively than when it is not. Our results might explain why EHAs seem more attractive in some markets than in others, why some service providers have exclusive arrangements even for handset models that do not seem popular, and how some handset vendors enjoy high market shares despite having many exclusive models. Furthermore, an EHA may lower the handset vendor's incentives to improve handset quality, supporting concerns raised by proponents of wireless network neutrality.

Key words: competitive strategy; distribution channel; exclusive arrangements; game theory; raising rival's costs; wireless network neutrality
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1. Introduction

In many countries, wireless service providers bundle handsets with subscriptions to their wireless service, and handset vendors realize a bulk of their sales through service providers (Accenture 2005).[1] At times, a service provider and a handset vendor may enter into an exclusive arrangement, whereby the handset vendor makes one of its handset models available only to subscribers of that service provider. For example, in the United States, many handset models from LG Electronics, including top-selling ones such as the Chocolate, enV, and Venus, have been exclusive to Verizon Wireless (subscribers) (Rural Cellular Association (RCA) 2008). In fact, a 2010 U.S. industry report of the Federal Communication Commission (FCC) suggests that the practice may be fairly prevalent; of the 67 smartphones launched in 2008 and 2009, 32 were launched exclusively (FCC 2010). From the data in this report, Table 1 shows the proportion of handsets launched exclusively by the four largest U.S. service providers.[2] Table 1 also provides similar information for smartphones available in the United States as of August 2011.[3] Examples of exclusive handsets in other countries include the Blackberry Storm from Research in Motion (RIM), which was exclusive to Vodafone in Germany, Italy, Spain, and the United Kingdom (Vodafone 2008); and the DEXT from Motorola, which was exclusive to Optus in Australia (Optus 2010). In this paper, we examine the competitive rationale and the implications of such exclusive arrangements.

Now, some exclusive handsets may very well be "branded variants" (Bergen et al. 1996); that is to say, they may be variants of handsets offered through another service provider from the same handset vendor, with minor differences in features. Branded variants are primarily meant to deter comparison shopping across service providers, rather than to address an underlying market need for variety (because of heterogeneity in consumer tastes). In such

[1] Examples of such countries include Argentina, Australia, Chile, France, Germany, Italy, Japan, Singapore, South Korea, Spain, Taiwan, the United Kingdom, and the United States (Euromonitor 2009; Mintel 2009a, b).

[2] These service providers account for about 90% of the subscribers in the market (Columbia Institute for Tele-Information 2011).

[3] Refer to Appendix A for the list of handsets used in this classification.

Table 1 Prevalence of Exclusive Handsets in the United States

	Smartphones launched in 2008–2009[a]			Smartphones available in August 2011[b]		
Service provider	Exclusive launch	Total	% exclusive	Exclusive launch	Total	% exclusive
AT&T	15	21	71	12	20	60
Verizon	9	17	53	10	20	50
Sprint	3	14	21	3	13	23
T-Mobile	5	12	42	7	13	54

[a] *Source*: FCC's 14th wireless market report (FCC 2010). [b] *Source*: Service provider websites and press releases.

instances, an exclusive arrangement may not truly limit the handset vendor's ability to distribute handsets that are desirable to consumers. But, arguably, in other instances, including the examples noted earlier, the handset vendor is limited in this fashion. We are interested in this latter type of exclusive handset arrangement (EHA). For the exclusive handsets available in the United States as of August 2011, the authors found that a close variant was not available from another service provider in more than two-thirds of the instances (see Appendix A for details).

At first glance, the rationale behind this practice might appear straightforward. An EHA is often regarded as a means for a service provider to differentiate itself from other providers (e.g., CTIA 2007, AT&T Wireless 2009). Conventional wisdom suggests that a service provider can attract more subscribers by selling a desirable handset exclusively. The service provider, in turn, compensates the handset vendor for making its handset exclusive. Thus, both the service provider and the handset vendor potentially stand to benefit from such an arrangement.

But on closer examination, certain aspects are not quite clear. To begin with, when is an EHA mutually beneficial? For instance, whereas some handset vendors, such as LG and Samsung, have had EHAs for many of their handsets, others, such as Nokia and Motorola, have traditionally had relatively few.[4] Why might some handset vendors find this practice more attractive? Also, handsets exclusive in some markets may be nonexclusive in others. For instance, many of LG's handsets were exclusive in the United States but nonexclusive in the United Kingdom. Why might EHAs be more attractive in some markets than in others? Thus, the drivers for this practice need more careful investigation.

A second issue is, how does an EHA affect handset vendor market share? Typically, one might expect that exclusivity leads to lower handset market share. For instance, many industry analysts believe that Apple's exclusive iPhone arrangements have kept its market share "artificially low" (e.g., Elmer-Dewitt 2009a, b; Savitz 2009).[5] However, a distinctive aspect of LG's business strategy in the U.S. market has been its EHAs (e.g., *Investor's Business Daily* 2003, RCA 2008), and yet during this time, it grew substantially at the expense of more established players. How was LG able to increase its market share despite having relatively many of its handsets sold exclusively? In other words, does an EHA necessarily lead to lower market share?

A third issue is the potential for anticompetitive effects. In the United States, smaller service providers petitioned the FCC to ban the practice of selling exclusive handsets, arguing that it restricts service provider competition (RCA 2008). Furthermore, a significant concern in the blocked merger of AT&T Wireless (AT&T) and T-Mobile was that the merged entity may use EHAs to hinder competition (e.g., Sprint Nextel 2011). But in France, the Supreme Court ruled that EHAs were not anticompetitive since competing handsets were still available to excluded service providers (ZDNet France 2010). Policy makers have also been concerned about the impact of this practice on handset innovation (e.g., U.S. Senate Hearing 2009). Whereas some economists and legal scholars believe that EHAs foster innovation (e.g., Hahn et al. 2007, Ehrlich et al. 2010), others argue that it has the opposite effect (e.g., Wu 2007, Frieden 2009). Such concerns also relate to the broader debate on "wireless network neutrality" regarding whether service providers should be allowed to restrict the features and availability of certain handsets and applications. Thus, the competitive impact of this practice needs more formal examination.

Our objective in this paper is to conduct a model-based examination of the rationale for a service provider and a handset vendor to form an EHA and its competitive implications, explicitly accounting for handset and service competition. Similar exclusive arrangements are also used in other industries. For instance, retailers have exclusive merchandise agreements with national brand manufacturers, videogame

[4] A 2008 petition to the FCC against exclusive handsets identifies LG and Samsung as having the highest number of EHAs (RCA 2008).

[5] Apple's U.S. market share has since increased after its EHAs with AT&T ended (NPD Group 2011).

console makers have exclusive third-party video games, and satellite and cable network companies have exclusive content and channels. To make our analysis more concrete, in this paper we focus on the wireless industry.

1.1. Main Results and Contribution

We find that an EHA may serve a dual strategic purpose. By restricting its handsets to one service provider, a handset vendor may be able to induce a rival handset vendor to compete less aggressively when supplying handsets; we refer to this as the *supply price effect*. At the same time, a service provider may be able to raise its rival's handset costs by limiting the handsets available to the rival; we refer to this as the *cost-raising effect*. We find that an EHA may be mutually profitable only if the exclusive handset is not too attractive to consumers relative to competing handsets. Interestingly, a handset vendor's market share may be higher when its handset is sold exclusively than when it is not. Our results might explain, for instance, why Nokia and Motorola, who have traditionally been the leading vendors in many markets, have relatively few EHAs compared with LG and Samsung, for example, and why Apple may have shifted away from having EHAs. Our results might also explain why some handset vendors seem to enjoy high market shares despite having many of their handset models sold exclusively, whereas, in other instances, exclusive handsets are blamed for artificially low handset vendor market share and profits.

Although conventional wisdom might suggest that service providers use exclusive handsets primarily to differentiate themselves from their competitors, we find that the cost-raising effect may instead be the main source of advantage a service provider gains from the EHA. In fact, a service provider may benefit even if the exclusive handset is relatively less attractive than competing handsets. Our results might thus explain why some service providers have several exclusive handsets (as seen, for instance, in Table 1); even if not all of these handsets are particularly attractive to consumers, they may still help by raising the rival's costs. Our analysis further sheds light on how service and handset market factors may influence the occurrence of EHAs and the value that firms gain from them. For instance, we find that the scope for EHAs may be higher when the consumers' propensity to use service is higher. This might explain, for instance, why exclusive handsets are more prevalent in the United States than in the United Kingdom. We also find that the service provider value from an EHA may be higher when its service differentiation is higher. Therefore, service providers may be well advised to not ignore their service dimension even as they strive to differentiate themselves through their handsets.

Two aspects of our model distinguish our approach from that used in prior work and may be useful to model similar situations. First, we do not restrict consumers to consume the bundled components (handset and service) in fixed proportion; consumers may consume multiple units of wireless service (i.e., cellphone minutes), and their demand for service is linked to their relative preference for the service provider. This allows us to distinguish between handset and service demand and investigate the impact of exclusive handsets on service pricing and usage. Second, we incorporate vertical and horizontal differentiation for both handset and service dimensions. This allows us to study how handset vendor and service provider characteristics, including their asymmetry, influence the outcomes. In this regard, we follow a demand modeling approach introduced by Dukes et al. (2006) in the context of retailer store–national brand choice decisions. The advantage of this approach is that demand across distribution regimes can be modeled in a manner that is consistent with individual-level behavior and is yet analytically tractable. We extend their approach to our setting with service–handset bundles and show that analytical solutions can be obtained even when the handset vendors are asymmetric and the distribution regime is exclusive.[6]

1.2. Relationship to Previous Research

1.2.1. Complementary Goods. Prior work on complementary goods has examined tying and bundling arrangements (e.g., Whinston 1990, Chen 1997, Choi and Stefanadis 2001, Ghosh and Balachander 2007, Basu and Vitharana 2009, Balachander et al. 2010) and component compatibility strategies (e.g., Matutes and Regibeau 1988, Economides 1989, Matutes and Regibeau 1992, Farrell et al. 1998). However, in much of this literature, a single firm provides both components. Furthermore, such arrangements essentially bind two components to be exclusively combined with each other, whereas, in our context, only the handset is exclusively bound to a service provider.

1.2.2. Channel Structure. Our work adds to the literature on determinants of distribution channel structure (e.g., McGuire and Staelin 1983, Coughlan 1985, Moorthy 1988, Coughlan and Wernerfelt 1989, Purohit 1997, Chiang et al. 2003, Desai et al. 2004, Kumar and Ruan 2006, Zhao et al. 2009, Ofek et al. 2011). In particular, much of the prior research on exclusive arrangements in distribution channels has focused on two types of arrangements—namely,

[6] The solution approach in Dukes et al. (2006) relies on the symmetry between manufacturers and on the nonexclusive distribution regime being the equilibrium outcome.

exclusive dealing (e.g., Mathewson and Winter 1987, Besanko and Perry 1993, O'Brien and Shaffer 1997, Bernheim and Whinston 1998, Lal and Villas-Boas 1996, Martimort 1996, Heide et al. 1998, Stefanadis 1998, Simpson and Wickelgren 2007) and exclusive territories (e.g., Mathewson and Winter 1984; Rey and Tirole 1986; Dutta et al. 1994, 1999). Under *exclusive dealing*, a manufacturer requires a distributor to be exclusive to its brand. Under an *exclusive territory* arrangement, a manufacturer assigns distributors nonoverlapping territories in a market within which they have the exclusive right to sell the manufacturer's products.

The exclusive tie-in we examine in this paper constitutes a third type of arrangement, wherein a handset vendor assigns the exclusive right to sell its handsets to one service provider in the entire market. We find that such an arrangement leads to a different pattern of strategic interactions than identified in previous research. In particular, Lin (1990), O'Brien and Shaffer (1993), and Rey and Stiglitz (1995) show that exclusive dealing or exclusive territories can soften manufacturer competition; they find that an exclusive arrangement relaxes (downstream) competition between distributors, which, in turn, makes the (upstream) manufacturers' derived demand less elastic.[7] In contrast, we find that an EHA can moderate or intensify upstream competition. Moreover, even when an EHA moderates upstream competition, it does so despite the exclusive handset vendor facing more elastic demand. Rather, competition is moderated because, by restricting its supply of handsets to one service provider, the exclusive handset vendor may induce the rival handset vendor to compete less aggressively. Furthermore, from a service provider's perspective, we find that an EHA may effectively raise its rival's handset costs.

In ongoing work, Stennek (2008), Weeds (2009), and Hagiu and Lee (2012) examine the impact of exclusive content for television networks, and Lee (2007) examines exclusive games for videogame consoles. However, the thrust of their work is in studying exclusivity in two-sided markets; they do not consider competition between upstream firms. Researchers have also examined exclusivity contracts for advertising (e.g., Villas-Boas 1994, Dukes and Gal-Or 2003) and referral infomediaries (Chen et al. 2002). Their institutional contexts differ considerably from ours.

1.2.3. Raising Rival's Costs. Salop and Scheffman (1983) introduce the notion of raising rival's costs and propose that a dominant firm may adopt strategies to raise the input costs of the competitive fringe.[8] Krattenmaker and Salop (1986a, b) argue that an exclusionary arrangement preventing suppliers from supplying to a firm's rivals may be an effective cost-raising strategy. But, to our knowledge, this aspect of an exclusive distribution arrangement has not been formally studied. Much of the subsequent literature has examined whether a downstream producer may integrate with an upstream supplier to raise its rivals' costs (e.g., Salinger 1988, Ordover et al. 1990, Hart and Tirole 1990, Vickers 1995, Gaudet and Long 1996, Riordan 1998, Choi and Yi 2000, Chen 2001). The nature of upstream competition (all-or-nothing demand for inputs) and the behavior of the integrated firm (supplying inputs to a rival) examined in this context make it considerably different than the setting we study. Researchers have also examined cost-raising strategies in the context of exclusive dealing (Rasmusen et al. 1991, Shaffer 2005), supply of inputs to rivals (Economides 1998, Sibley and Weisman 1998), research and development (R&D) investments (Banerjee and Lin 2003), and outsourcing (Arya et al. 2008). Our work formally examines the cost-raising effect of exclusive distribution arrangements.

2. Model Description

We consider a market with two competing wireless service providers, S_A and S_B, and two competing handset vendors, H_1 and H_2. We examine a setting where handset vendors supply handsets to service providers, and service providers offer service subscriptions bundled with handsets to consumers. We assume that each handset vendor provides one handset model.[9] We do not model independent retailers who offer subscriptions from competing service providers. Our model may approximate the situation in markets where a majority of retail outlets are owned or exclusively franchised by service providers (such as the countries listed in footnote 1).

To begin with, we analyze the incentives for a focal handset vendor and a focal service provider to form an exclusive tie-in when a competing supply of handsets is available to all service providers. For instance, in the United States, when Apple was considering an EHA with AT&T, the Blackberry from RIM was available to all service providers. Accordingly, we examine the situation where H_1 must decide if its handset will be available exclusively through S_A or nonexclusively through both service providers, whereas H_2's

[7] Similarly, McGuire and Staelin (1983) show that manufacturers may prefer vertical separation over integration with their distributors because double marginalization makes their demand less elastic and softens manufacturer competition.

[8] Salop and Scheffman (1987) develop this more formally.

[9] In §I of the online electronic companion (available at http://dx.doi.org/10.1287/mksc.1120.0752), we examine an extension where there are three competing handset vendors, each providing one handset model.

handset is available to both service providers. Later, we discuss the implications when (i) H_1 may choose the service provider to tie in with (§5.1), (ii) service providers may make competing proposals to H_1 for an EHA (§5.2), and (iii) H_1 may tie in with S_A and H_2 may tie in with S_B (§5.3). Starting with the simpler scenario sheds light on the trade-offs faced by individual firms when considering an EHA and provides us with better intuition for the scenarios that follow. It also enables us to directly evaluate the French Supreme Court's argument that the availability of competing handsets should allay anticompetitive concerns regarding exclusive handsets.

2.1. Consumer Preferences and Buying Behavior

As such, consumers have preferences over combinations of handset, service provider, and minutes of cellphone usage. Modeling demand in this setting presents a challenge. We follow an approach introduced by Dukes et al. (2006) to model consumers' retailer store–national brand choice for semidurables and extend it to our context. This enables us to specify consumer preferences and decision making at the individual level while ensuring that the resulting demand functions are sufficiently tractable (even though they may be nonlinear).[10,11]

Specifically, we assume that consumers are aware of the handsets available in the market but are a priori uncertain about their preferences (or fit) for the handsets. A similar assumption is made in Shulman et al. (2009, 2010, 2011), Villas-Boas (2009), and Kuksov and Villas-Boas (2010). In our context, because handsets are semidurables that are replaced every few years and new handsets are introduced every few months, consumers may not be fully familiar with the latest handset features.[12] We assume that consumers learn their handset preference when they visit a service provider store. In particular, even when consumers may be aware of handset features, they may not be able to ascertain their preferences until they visit the store because of the "touch-and-feel" nature of the product.[13] Indeed, as a recent market study describes (Mintel 2008):[14]

> Retail stores are a critical channel for cell phones: Given the personal nature of such devices, consumers need to be able to see and use products in person before purchase.

Alternatively, drawing from behavioral decision research (e.g., Payne et al. 1993, Lichtenstein and Slovic 2006, Simonson 2008), it may also be that consumers have not a priori fully formed their preference and may "construct" their preference (through a process of deliberation) when they are at the store to make a purchase.[15] A similar assumption is made in Shugan (1980) and in Guo and Zhang (2012). Consistent with either interpretation, a J.D. Power market study found that, on average, consumers spend 56 minutes at the store for a typical cellphone transaction (Mintel 2008). We assume that the cost of visiting multiple service provider stores is sufficiently high so that all consumers make their buying decisions after visiting one service provider store.[16]

We recognize at the outset that our assumptions may not fully characterize all consumers in a market. Rather, we believe that our approach may provide a reasonable approximation of consumer behavior that is useful to develop an analytically tractable and yet flexible framework to study a complex setting. As in Dukes et al. (2006), the net impact of our assumptions is that consumers follow a sequential decision process: they first choose their service provider before their handset preferences are revealed and then choose the handset. As we show, this yields a multiplicative demand formulation that is considerably more tractable than that when consumers know their handset preference a priori and make their service–handset choice simultaneously or when they can visit multiple service provider stores without incurring any cost. In §F of the online electronic companion, we show that our main results are robust to these alternative consumer decision-making scenarios.

We assume that there is a unit mass of consumers. Let x and y be parameters that represent a consumer's taste for a wireless service and handset, respectively. We define these more precisely as we proceed.

[10] An individual-level model ensures that market demand under alternative distribution scenarios is internally consistent. Tractability is crucial as we need to solve for the successive pricing decisions of handset vendors and service providers.

[11] An alternative approach used in prior research is to model aggregate demand based on the preferences of a representative or "average" consumer who buys multiple units of each alternative. But in our context, as no individual consumer would typically buy multiple service–handset bundles, it is not clear that an aggregate approach is valid. It is also not clear how one would model demand for cellphone minutes for a representative consumer who has multiple subscriptions.

[12] The handset replacement cycle is roughly two years in the United States and three years in western Europe (Oppenheimer 2009).

[13] We thank the associate editor for suggesting this interpretation.

[14] According to a Euromonitor report, online sales accounted for less than 10% of overall handset sales in many markets (Euromonitor 2009).

[15] We thank an anonymous reviewer for this suggestion.

[16] In §E of the online electronic companion, we show that if consumers incur a disutility Δ to visit each service provider store and $V - 2\alpha^2 > \Delta > 2h$, then it is optimal for consumers to always visit only one service provider store even when service providers offer asymmetric product lines.

Let $U(i, j, q; x, y)$ denote the utility of a consumer with tastes (x, y) when she has signed up for S_i's service along with H_j's handset and uses $q \geq 0$ minutes of cellphone service, where $i \in \{A, B\}$ and $j \in \{1, 2\}$. We assume that the utility from service is independent of the utility from handsets such that $U(i, j, q; x, y)$ is additively separable into service and handset components as follows:

$$U(i, j, q; x, y) = U_S(i, q; x) + U_H(j; y), \tag{1}$$

where $U_S(\cdot)$ and $U_H(\cdot)$ are, respectively, the service and handset components. We also assume that the distribution of tastes for service (x) and handset (y) are independent. Consequently, the choice of handset does not affect service usage. This may be the case, for instance, when both handsets belong to the same category of phones (e.g., texting phones, smartphones) and have similar service capabilities but may differ in aspects such as brand image and industrial design that may not significantly impact service usage. In §G of the online electronic companion, we show that our main insights continue to hold when a handset of higher quality drives higher service usage, and thus, handset choice does impact service usage.

With regard to service preference, we assume that consumers are distributed uniformly along the unit interval $[0, 1]$, with S_A and S_B located at 0 and 1, respectively, and x denoting a consumer's location. We assume that a consumer located closer to a service provider derives a higher utility from its service. For instance, service providers usually differ in their network coverage across different regions in the market (e.g., *Consumer Reports* 2009). The distance of a consumer from the service provider in our model may then correspond to the quality of network reception she receives from that service provider; consumers located closer to a service provider would correspond to those living in areas with better network reception from that service provider. Now, a consumer's preference for a service provider is also likely to influence how much of its service she will use. For instance, network reception may not only affect the quality of calls but also influence how many calls the consumer makes and the duration of each call. Accordingly, we assume that a consumer located closer to a service provider not only derives higher utility from its service but, as a result, will use more of its service.

We model the relation between cellphone usage and relative preference for service providers as follows. We assume that the utility from cellphone service is strictly concave and quadratic in the number of cellphone minutes used and that the marginal utility from an additional cellphone minute decreases linearly with the distance from the service provider. Specifically,

$$U_S(A, q; x) = V_S + \left[\alpha + \frac{1}{2}\delta_S - sx\right]q - \frac{\beta}{2}q^2, \tag{2a}$$

$$U_S(B, q; x) = V_S + \left[\alpha - \frac{1}{2}\delta_S - s(1-x)\right]q - \frac{\beta}{2}q^2, \tag{2b}$$

where $V_S > 0$ is the base utility from cellphone service; $\alpha > 0$, $\beta > 0$, and δ_S are demand parameters that determine consumers' base propensity to consume service from each service provider; and $s > 0$ is the sensitivity of a consumer's service usage to her preference for the service provider. Without loss of generality, we normalize β to 1. The asymmetry in service quality between the service providers is captured by δ_S. If $\delta_S > 0$, then, all else being equal, consumers on average have a higher propensity to consume service when subscribing to S_A than to S_B. This could be because S_A's network quality or coverage is, on average, superior to S_B's. For instance, Verizon is considered to be the overall leader in network quality across the United States (e.g., *Consumer Reports* 2009). Furthermore, when $\delta_S > 0$, more consumers would subscribe to S_A than to S_B, all else being equal. Similarly, if $\delta_S < 0$, then, on average, all else being equal, consumers have a higher propensity to consume S_B's service than S_A's and more consumers would subscribe to S_B than to S_A. We interpret δ_S as a measure of vertical service differentiation and refer to it as *relative service quality*. We say that S_A is a better (poorer) service provider than S_B if $\delta_S > 0$ ($\delta_S < 0$). In contrast, s provides a measure of horizontal service differentiation and we refer to it simply as *service differentiation*; if s is larger, consumers have stronger preferences for their nearer service provider, and their service provider choice is less price sensitive.

With regard to handset preference, we assume that consumers are distributed uniformly along the unit interval $[0, 1]$, with H_1 and H_2 located at 0 and 1, respectively, and y denoting a consumer's location, such that a consumer derives higher utility from the nearer handset vendor. Specifically,

$$U_H(1; y) = V_H + \tfrac{1}{2}\delta_H - hy, \tag{3a}$$

$$U_H(2; y) = V_H - \tfrac{1}{2}\delta_H - h(1-y), \tag{3b}$$

where $V_H > 0$ is the base utility from a handset, $h > 0$ is a measure of horizontal differentiation between handsets, and δ_H is a measure of vertical differentiation that could be due to unique aspects such as brand name or specific handset features. We note that δ_H also represents the average relative preference across consumers for H_1's handsets over H_2's. We refer to δ_H as *relative handset quality* and say that H_1 has a better (poorer) handset than H_2 if $\delta_H > 0$ ($\delta_H < 0$). We refer

to h simply as *handset differentiation*. We assume that consumers are a priori uncertain about their relative handset preference. We further assume that consumers are aware of the nature of uncertainty in their preference and hold beliefs that are consistent with reality. Specifically, the average relative preference δ_H and the distribution of y are common knowledge. A consumer does not initially know her individual preference y and learns it when she visits a service provider store.

Let $V = V_S + V_H$ denote the overall base utility from having and using a cell phone. We impose the following restrictions that are sufficient to ensure interior solutions when solving for equilibrium:[17]

$$\begin{aligned} s &\in \left[\tfrac{1}{3}\alpha, \alpha\right], \quad |\delta_S| \le s\left(\tfrac{1}{50} + \tfrac{3}{5}\left(s - \tfrac{4}{5}\right)^2\right), \\ h &\in \left[\tfrac{1}{4}\alpha^2, \tfrac{7}{10}\alpha^2\right], \quad |\delta_H| \le \tfrac{1}{2}h(6h-1). \end{aligned} \tag{4}$$

2.2. Sequence of Decisions

We assume the following sequence of decisions.

Stage 1. H_1 decides whether or not to make a proposal to S_A for an EHA. If H_1 does not make a proposal, then the distribution regime is nonexclusive (NE), and Stage 2 is skipped.

Stage 2. H_1 proposes the wholesale price, w_1^E, for an EHA. S_A can either accept or reject H_1's proposal. If S_A accepts the proposal, then the distribution regime is exclusive (E). Otherwise, the distribution regime is nonexclusive (NE).

Stage 3. In the nonexclusive distribution regime, H_1 and H_2 simultaneously set their handset wholesale prices, w_1^{NE} and w_2^{NE}, respectively. In the exclusive distribution regime, H_2 sets its handset wholesale price, w_2^E.

Stage 4. Service providers simultaneously set upfront fixed fees for the subscription–handset bundles they offer and per-minute usage fee for cellphone minutes. We use F_{ij}^C to denote the fixed fee for H_j's handset bundled with S_i's subscription and p_i^C to denote S_i's usage fee, where $C \in \{E, NE\}$ indicates the distribution regime.

Stage 5a. Consumers observe the availability of handsets as well as the prices at each service provider and decide which service provider to visit.

Stage 5b. At the service provider store, consumers learn their handset preference and choose between the service–handset bundles available from that service provider.

We assume that H_1 proposes the wholesale price at which it can make its handset exclusive to S_A, which puts H_1 in a better bargaining position relative to S_A (because it makes a take-it-or-leave-it offer). In §5.2, we discuss the implications when H_1 and S_A follow a Nash bargaining process and may use a side payment to redistribute the gains. We assume that if S_A is indifferent between accepting and rejecting H_1's proposal, then it accepts the proposal. We assume that H_2 observes whether S_A accepted H_1's proposal and is thus aware of the distribution regime when setting its wholesale price but is not aware of the terms of the proposal (w_1^E). Thus, we maintain the information structure with regard to handset wholesale price decisions across both distribution regimes. In particular, H_1 does not become a Stackelberg price leader by virtue of having an EHA.[18]

We assume that service providers set prices taking handset wholesale prices to be given. In practice, handset wholesale prices are typically set on an annual or semiannual basis, whereas service providers update their prices more frequently. For instance, handset retail prices may be revised on a weekly basis. Consistent with what is typically observed in practice, we assume that a service provider charges the same usage fee for all its subscribers regardless of the handset they use. Service providers can, however, charge handset-specific upfront fees. In §J of the online electronic companion, we examine the setting where service providers do not charge a usage fee and offer "unlimited minutes" flat-rate plans. Because network capacity investments are typically "lumpy" and are of the fixed-cost variety, we assume that service providers do not face any marginal costs for providing service. In §6, we discuss the implications when service providers face a constant marginal cost for providing service.

We assume that firms are profit maximizers and correctly anticipate outcomes in future stages. Let $C \in \{E, NE\}$ denote the distribution regime indicating whether H_1 is exclusive ($C = E$) or nonexclusive ($C = NE$). Let D_{ij}^C be the demand for S_i's subscriptions bundled with H_j's handset, and let Q_i^C be the total demand for cellphone minutes from S_i's subscribers under regime C. By definition, we have $D_{B1}^E = 0$. Let $\Pi_{S_i}^C$ and $\Pi_{H_j}^C$, respectively, denote S_i's and H_j's corresponding profits. We have

$$\Pi_{S_i}^C = p_i^C Q_i^C + \sum_{j=1}^{2} (F_{ij}^C - w_j^C) D_{ij}^C, \tag{5a}$$

$$\Pi_{H_j}^C = w_j^C (D_{Aj}^C + D_{Bj}^C). \tag{5b}$$

We assume that consumers are rational, risk-neutral, utility maximizers. For a consumer with

[17] These restrictions mainly ensure that H_2 has positive market share among S_A's subscribers in the exclusive regime. Outside this parameter range, H_2's demand may be kinked in the relevant range of analysis and a pure-strategy equilibrium may not exist. Also, the upper bound on s ensures that the service provider market is fully covered.

[18] In §H of the online electronic companion, we examine a setting where H_2 is aware of H_1's wholesale price under both distribution regimes, and thus H_1 is a Stackelberg price leader.

Table 2 Model Notation

Model parameters	
α	Consumers' propensity to use wireless service
s	Service differentiation
h	Handset differentiation
δ_S	Relative service quality (S_A's quality relative to S_B)
δ_H	Relative handset quality (H_1's quality relative to H_2)
Model variables	
Subscript i	Variables pertaining to service provider S_i, $i \in \{A, B\}$
Subscript j	Variables pertaining to handset vendor H_j, $j \in \{1, 2\}$
Superscript C	Distribution regime: $C = NE$ for nonexclusive regime and $C = E$ for exclusive regime
F_{ij}^C	Fixed fees for subscription–handset bundle S_i-H_j in distribution regime C
p_i^C	Usage fees for S_i's service in distribution regime C
w_j^C	H_j's handset wholesale price in distribution regime C
$\hat{U}^C(i, j, q; x, y)$	Indirect utility of a consumer, with service–handset preference (x, y), subscribing to S_i's service bundled with H_j's handset and using q units of service
Q_i^C	Total demand for cellphone minutes for S_i in distribution regime C
D_{ij}^C	Demand for subscription–handset bundle S_i-H_j in distribution regime C
$\hat{x}^C$	S_A's subscriber market share in distribution regime C
$\hat{y}_i^C$	H_1's share of S_i's subscribers in distribution regime C
$\Pi_{S_i}^C, \Pi_{H_j}^C$	S_i's and H_j's profits in distribution regime C

tastes (x, y), let $\hat{U}^C(i, j, q; x, y)$ denote the net utility or indirect utility accounting for prices when she has signed up for S_i's service bundled with H_j's handset and uses $q \geq 0$ minutes of cellphone service under distribution regime C. $\hat{U}^C(i, j, q; x, y)$ is given by

$$\hat{U}^C(i, j, q; x, y) = U(i, j, q; x, y) - p_i^C q - F_{ij}^C. \quad (6)$$

Table 2 summarizes our model notation.

3. Mutual Incentives for an EHA

In this section, we examine when H_1 and S_A may form an EHA. We use the sequential equilibrium as our solution concept. In particular, H_2's wholesale price decision in Stage 3 under the exclusive regime is based on its beliefs about H_1's wholesale price in the EHA. Furthermore, H_1 and S_A base their EHA decisions on their beliefs about H_2's wholesale price in the exclusive and nonexclusive regimes. In a sequential equilibrium, these beliefs must be consistent.[19] We solve by backward induction. As a matter of notation, for any variable z, we use z^* to denote its value in a subgame equilibrium of the service provider pricing decisions and z^{**} to denote its value in a subgame equilibrium of the handset vendor pricing decisions.

[19] To fix these beliefs endogenously and ensure uniqueness of the equilibrium, we introduce a small tremble in H_1's decision in Stage 1 so that these beliefs are not off the equilibrium path even if H_1 decides not to make a proposal.

We first examine the nonexclusive outcome in the subgame at Stage 3 (when H_1 decides not to make a proposal, or it makes a proposal, but is rejected). Then, we analyze the exclusive outcome in the subgame at Stage 2 (assuming S_A accepts H_1's proposal). Finally, we examine the equilibrium of the overall game.

3.1. Market Outcomes Without an EHA

3.1.1. Consumer Decisions. Consumers follow a sequential decision process. We solve for consumer decisions starting from the last stage after their handset preference is revealed. Suppose that a consumer at x subscribes to S_i's service and has handset preference y. Let q_{ix}^{NE} be this consumer's optimal level of service usage. We obtain q_{ix}^{NE} by maximizing $\hat{U}^{NE}(i, j, q; x, y)$ with respect to q. We find

$$\begin{aligned} q_{Ax}^{NE} &= \alpha + \tfrac{1}{2}\delta_S - sx - p_A^{NE}, \\ q_{Bx}^{NE} &= \alpha - \tfrac{1}{2}\delta_S - s(1-x) - p_B^{NE}. \end{aligned} \quad (7)$$

Note that q_{ix}^{NE} is increasing in the propensity to consume service from the service provider, decreasing in the distance from the service provider, and decreasing in the service provider's usage fee. Furthermore, q_{ix}^{NE} is independent of the handset chosen, because this does not affect the utility from service consumption. Now, consider this consumer's handset choice. Her utilities from the two service–handset bundles are given by

$$\begin{aligned} \hat{U}^{NE}(i, 1, q_{ix}^{NE}; x, y) &= V + \tfrac{1}{2}(q_{ix}^{NE})^2 \\ &\quad + \tfrac{1}{2}\delta_H - hy - F_{i1}^{NE}, \quad (8a) \\ \hat{U}^{NE}(i, 2, q_{ix}^{NE}; x, y) &= V + \tfrac{1}{2}(q_{ix}^{NE})^2 - \tfrac{1}{2}\delta_H \\ &\quad - h(1-y) - F_{i2}^{NE}. \quad (8b) \end{aligned}$$

Let $y = \hat{y}_i^{NE}$ denote the handset preference of a consumer who is indifferent between choosing either of these bundles at S_i's store. Setting $\hat{U}^{NE}(i, 1, q_{ix}^{NE}; x, \hat{y}_i^{NE}) = \hat{U}^{NE}(i, 2, q_{ix}^{NE}; x, \hat{y}_i^{NE})$, we obtain

$$\hat{y}_i^{NE} = \frac{h + \delta_H + F_{i2}^{NE} - F_{i1}^{NE}}{2h}. \quad (9)$$

We note that $\hat{y}_i^{NE}$ is also the ex ante probability that a consumer who visits S_i buys H_1's handset.

Consider next how a consumer at x decides which service provider store to visit; she must take into account her optimal service usage and the expected outcome of her handset choice process. For a consumer at x, let $\bar{U}^{NE}(i; x)$ be the expected utility of visiting S_i's store. This is given by

$$\begin{aligned} \bar{U}^{NE}(i; x) &= E_y[\hat{U}^{NE}(i, 1, q_{ix}^{NE}; x, y) \mid y \leq \hat{y}_i^{NE}]\Pr(y \leq \hat{y}_i^{NE}) \\ &\quad + E_y[\hat{U}^{NE}(i, 2, q_{ix}^{NE}; x, y) \mid y > \hat{y}_i^{NE}] \end{aligned}$$

$$\cdot \Pr(y > \hat{y}_i^{NE})$$
$$= V + \tfrac{1}{2}(q_{ix}^{NE})^2 - \tfrac{1}{2}\delta_H - \tfrac{1}{2}h - F_{i2}^{NE} + h(\hat{y}_i^{NE})^2$$
$$= E_y[\hat{U}^{NE}(i, 2, q_{ix}^{NE}; x, y)] + h(\hat{y}_i^{NE})^2. \quad (10)$$

Thus, $\bar{U}^{NE}(i; x)$ can be expressed as the sum of two components: the first component is the consumer's expected utility if she were constrained to buy only H_2's handset when subscribing to S_i, and the second component is her expected utility from having the additional alternative of choosing H_1's handset. One may think of the first component as the consumer's value from S_i's "baseline" subscription option (with H_2's handset) and the second component as the consumer's value from the "handset variety" offered by S_i (over and above H_2's handset). We note that the consumer's value from handset variety is increasing in the probability that the consumer may actually buy the additional alternative. In other words, it is not simply the sheer variety that counts, but rather how attractive the variety actually is. In particular, the value from handset variety will depend on how each handset is priced and is thus determined endogenously. Let $\hat{x}^{NE}$ be the location of the consumer indifferent between visiting either service provider. Setting $\bar{U}^{NE}(A; \hat{x}^{NE}) = \bar{U}^{NE}(B; \hat{x}^{NE})$, we obtain

$$\hat{x}^{NE} = \frac{s + \delta_S + p_B^{NE} - p_A^{NE}}{2s} + \frac{F_{B2}^{NE} - F_{A2}^{NE}}{s(2\alpha - s - p_A^{NE} - p_B^{NE})} + \frac{h(\hat{y}_A^{NE})^2 - h(\hat{y}_B^{NE})^2}{s(2\alpha - s - p_A^{NE} - p_B^{NE})}, \quad (11)$$

where the first term captures the relative attractiveness of consuming S_A's service over S_B's, the second term captures the relative attractiveness of S_A's upfront fees over S_B's (with H_2's handset), and the last term captures the relative attractiveness of S_A's handset variety over S_B's.[20]

We note that $\hat{x}^{NE}$ also represents S_A's subscriber market share, and $\hat{y}_i^{NE}$ also represents H_1's market share among S_i's subscribers. Given the sequential consumer decision process, market demand for each subscription–handset bundle is multiplicative:

$$D_{A1}^{NE} = \hat{x}^{NE}\hat{y}_A^{NE}, \quad D_{B1}^{NE} = [1 - \hat{x}^{NE}]\hat{y}_B^{NE},$$
$$D_{A2}^{NE} = \hat{x}^{NE}[1 - \hat{y}_A^{NE}], \quad D_{B2}^{NE} = [1 - \hat{x}^{NE}][1 - \hat{y}_B^{NE}]. \quad (12)$$

The total demand for cellphone minutes for each service provider is given by

$$Q_A^{NE} = \hat{x}^{NE}\left[\alpha + \tfrac{1}{2}\delta_S - \tfrac{1}{2}s\hat{x}^{NE} - p_A^{NE}\right],$$
$$Q_B^{NE} = [1 - \hat{x}^{NE}]\left[\alpha - \tfrac{1}{2}\delta_S - \tfrac{1}{2}s(1 - \hat{x}^{NE}) - p_B^{NE}\right]. \quad (13)$$

[20] In (11), the denominator for the second and third terms adjusts for the trade-off in up-front fees and handset to be comparable to the trade-off in service consumption; although a consumer consumes one service subscription and one handset, she consumes multiple units of the service.

3.1.2. Service Provider Pricing Decisions. As can be seen from (9) and (11)–(13), service provider demand is considerably nonlinear in prices. The analytical approach used in Dukes et al. (2006) is applicable when the upstream firms are symmetric and nonexclusive. But in our setting, handset vendors are asymmetric, and we also need to examine an exclusive distribution regime. Furthermore, in our context, service providers have an additional pricing decision: service usage fees. Thus, we adopt a different analytical approach than Dukes et al. (2006). As shown in Lemma 1 in Appendix B, we exploit the inherent structure of demand to obtain analytical solutions. Specifically, we reformulate each service provider's optimization problem in terms of the mix between the two handset–subscription alternatives ($\hat{y}_i^{NE}$) and the subscription market share ($\hat{x}^{NE}$), as follows:

$$\max_{F_{ij}^{NE}, p_i^{NE}} \Pi_{S_i}^{NE} = \max_{\hat{x}^{NE}, \hat{y}_i^{NE}, p_i^{NE}} \Pi_{S_i}^{NE}, \quad (14)$$

where we have substituted for F_{ij}^{NE} in terms of $\hat{x}^{NE}$ and $\hat{y}_i^{NE}$ using (9) and (11). Intuitively, for each service provider, we solve for the optimal usage fee and mix between handset alternatives conditional on the subscriber market share of the service provider, and then we solve for the optimal subscriber market share. Lemma 1 in Appendix B describes the service providers' equilibrium strategies.

We find that handsets per se do not impact the competitive interaction between service providers as they are common to both service providers. The better service provider (S_A if $\delta_S > 0$, S_B if $\delta_S < 0$) attracts a larger subscriber market share. S_A's equilibrium subscriber market share is given by

$$\hat{x}^{NE^*} = \frac{1}{2} + \frac{2(2\alpha - s)}{3s(8\alpha - 5s)}\delta_S. \quad (15)$$

In deciding their fixed fee and usage fee, service providers must take into account the variation in usage across their subscriber base. The marginal subscriber for each service provider is its lightest user, and its heavier users are located closer to the service provider. Consequently, for a given level of net utility delivered to the marginal subscriber (i.e., holding $\hat{x}^{NE}$ constant), it is always optimal to charge a positive usage fee such that more surplus can be extracted from the heavier users who are located closer. We find that the usage fee is increasing in service differentiation (s) as this determines the extent of variation in usage between the heaviest and lightest user. We also find that the better service provider charges a higher usage fee because it has a larger subscriber base and, therefore, a larger variation in usage across subscribers. With regard to the fixed fee, we find that the service provider margin $F_{ij}^{NE^*} - w_j^{NE}$ is increasing

in the consumers' propensity to use the service (α). When α is higher, consumers incur a higher disutility to switch from their closer service provider to the rival, which makes them relatively less price sensitive. The service provider margin follows an inverted-U relation with s. When s is higher, for a given level of service usage, a consumer incurs a higher disutility when she switches service providers. However, the consumer's optimal service usage level is decreasing in s. Thus, her absolute level of utility when subscribing to either service provider is lower when s is higher, and therefore the difference in their utilities may be lower. Consequently, the price sensitivity of consumers follows an inverted-U relation with s. We also find that the better service provider charges a higher margin for the fixed fee as consumers are willing to pay a premium for its service. Finally, we find that service provider profits are also increasing in α and follow an inverted-U relation with s, and the better service provider earns higher profits.

3.1.3. Handset Vendor Pricing Decisions. Given the symmetry in supply configuration, handset vendors have the same market share at each service provider (see Lemma 1 in Appendix B). Hence, the derived demand for handsets is independent of the competitive interaction between service providers and is determined only by handset characteristics. In equilibrium, the better handset vendor charges a higher wholesale price, has a higher share of each service provider's subscribers, and earns higher profits. Lemma 2 in Appendix B describes the results.

To summarize, in the nonexclusive regime, the competitive interaction in the handset and service markets are essentially independent of each other, and the firms compete solely based on their individual merits. We next examine how this changes in the exclusive regime.

3.2. Market Outcomes with an EHA

3.2.1. Consumer Decisions. As before, consumers follow a sequential decision process. But whereas a consumer subscribing to S_A still has two handset options, a consumer subscribing to S_B has only one. Let q^E_{ix} denote the optimal service usage for a consumer at x when using S_i's service. As before, we have

$$\begin{aligned} q^E_{Ax} &= \alpha + \tfrac{1}{2}\delta_S - sx - p^E_A, \\ q^E_{Bx} &= \alpha - \tfrac{1}{2}\delta_S - s(1-x) - p^E_B. \end{aligned} \tag{16}$$

Considering the handset choice of a consumer who visits S_A, let $y = \hat{y}^E_A$ be the handset preference of a consumer who is indifferent between purchasing either handset. We have

$$\hat{y}^E_A = \frac{h + \delta_H + F^E_{A2} - F^E_{A1}}{2h}. \tag{17}$$

Considering the consumer's choice of service provider, let $\bar{U}^E(i;x)$ be the net expected utility for a consumer at x if she subscribes to S_i. We have

$$\begin{aligned} \bar{U}^E(A;x) &= V + \tfrac{1}{2}(q^E_{Ax})^2 - \tfrac{1}{2}\delta_H \\ &\quad - \tfrac{1}{2}h - F^E_{A2} + h(\hat{y}^E_A)^2, \end{aligned} \tag{18a}$$

$$\bar{U}^E(B;x) = V + \tfrac{1}{2}(q^E_{Bx})^2 - \tfrac{1}{2}\delta_H - \tfrac{1}{2}h - F^E_{B2}. \tag{18b}$$

Comparing (18a) and (18b) with (10), we note that, relative to the nonexclusive regime, all else being equal, in the exclusive regime, a consumer expects lower utility from subscribing to S_B because of the lower variety of handsets offered by S_B. Let the consumer indifferent between visiting either service provider store be located at $x = \hat{x}^E$. We have

$$\begin{aligned} \hat{x}^E &= \frac{s + \delta_S + p^E_B - p^E_A}{2s} + \frac{F^E_{B2} - F^E_{A2}}{s(2\alpha - s - p^E_A - p^E_B)} \\ &\quad + \frac{h(\hat{y}^E_A)^2}{s(2\alpha - s - p^E_A - p^E_B)}. \end{aligned} \tag{19}$$

We derive market demand as before.

3.2.2. Service Provider Pricing Decisions. We solve for the service provider equilibrium strategies by reformulating their optimization problems as before. Lemma 3 in Appendix B describes the equilibrium outcome. Handsets now do influence service provider interactions. S_A's equilibrium subscriber market share is given by

$$\hat{x}^{E^*} = \frac{1}{2} + \frac{2(2\alpha - s)}{3s(8\alpha - 5s)}\delta_S + \frac{4}{3s(8\alpha - 5s)}h(\hat{y}^{E^*}_A)^2, \tag{20}$$

where $\hat{y}^{E^*}_A$ is the probability that a consumer visiting S_A buys H_1's handset in equilibrium, given by[21]

$$\hat{y}^{E^*}_A = \frac{h + \delta_H + w^E_2 - w^E_1}{2h}. \tag{21}$$

Comparing (20) with (15), we note that, all else being equal, S_A enjoys a higher market share in the exclusive regime relative to the nonexclusive regime. Let $\delta^*_E = (4/(3s(8\alpha - 5s)))h(\hat{y}^{E^*}_A)^2$ denote S_A's additional market share in the exclusive regime compared to the nonexclusive regime. We will refer to δ^*_E as S_A's *market advantage* from the EHA. The extent of this advantage directly depends on $h(\hat{y}^{E^*}_A)^2$, the consumer utility from the additional handset variety provided by S_A. It also depends on service characteristics, α and s, which determine how the additional handset variety influences consumers' choice of service providers. S_A's market advantage from an EHA is decreasing in α and is initially decreasing and then increasing in s; as

[21] More precisely, $\hat{y}^{E^*}_A = \max[\min[(h + \delta_H + w^E_2 - w^E_1)/(2h), 1], 0]$. Equation (21) holds for the wholesale prices relevant for analysis.

discussed earlier, a higher α makes its less attractive for consumers to switch service providers, whereas the attractiveness of switching is initially decreasing and then increasing with s.

S_A's profits are strictly increasing in its market advantage δ_E^* (see Lemmas 1 and 3 in Appendix B). Interestingly, S_A benefits when H_2's wholesale price is higher (δ_E^* is increasing w_2^E). Even though an increase in H_2's wholesale price is common to both service providers, it affects S_B to a greater extent because S_A has an exclusive, alternative supply of handsets from H_1 and is less reliant on H_2's handsets. In particular, when w_2^E is higher, S_A has the flexibility to price the handsets so as to shift demand to H_1's handset (which translates to a higher $\hat{y}_A^{E^*}$ and, therefore, a higher δ_E^*). More generally, δ_E^* is increasing in the wholesale price differential, $w_2^E - w_1^E$; i.e., S_A benefits if H_2's handsets were to become relatively more expensive than H_1's in terms of their wholesale price.

Thus, conceptually, one can break down the effect of the EHA on service providers into two components: (i) a variety effect and (ii) a cost-raising effect. By *variety effect*, we mean the market advantage S_A gains solely from the additional handset variety it provides, taking the wholesale prices to be the same as without the EHA. In fact, taking $w_j^E = w_j^{NE^{**}}$, we have $\hat{y}_A^{E^*} = \hat{y}_A^{NE^{**}}$ and $\delta_E^* = (3h + \delta_H)^2/(27s(8\alpha - 5s)h)$. This is the contribution of handset variety alone to S_A's market advantage. By *cost-raising effect*, we mean the further market advantage S_A gains depending on how the wholesale price differential changes under the exclusive regime. If the wholesale price differential is higher under an EHA, then this further enhances S_A's advantage; i.e., it effectively raises S_B's handset costs more than it raises S_A's. In such cases, we say that the EHA "raises the rival's costs." Otherwise, it weakens S_A's advantage, and we say that it "reduces the rival's costs." Which of these two occurs is determined by the competitive interaction between the handset vendors.

3.2.3. Handset Vendor Pricing Decisions. The derived demand for handsets now also depends on the competitive interaction between service providers. H_1's prospects are closely tied to that of S_A's as it is exclusive to S_A. Similarly, H_2's prospects are closely linked to that of S_B's in that H_2's market share is increasing in that of S_B's. We note that S_A can never be worse off because its market advantage $\delta_E^* \geq 0$; in the worst case, S_A will accept H_1's proposal but not sell its handset ($\hat{y}_A^{E^*} = 0$) and will make the same profits as in the nonexclusive regime. Therefore, S_A always accepts H_1's proposal. Then, H_1's proposal maximizes its own profits in the exclusive regime. We solve for the equilibrium strategies in the usual manner. Lemma 4 in Appendix B describes the outcomes.

We find that the EHA may either intensify or moderate competition between handset vendors. On the one hand, H_1 faces a more elastic demand when it is exclusive than when it is not; H_1's demand in the exclusive regime depends not only on its share of S_A's subscribers but also on S_A's share of the market, both of which are decreasing in its wholesale price (see Lemma 5 in Appendix B). Consequently, all else being equal, H_1 has a tendency to set a lower wholesale price than when nonexclusive, which can potentially intensify competition. On the other hand, H_2 no longer faces direct competition from H_1 for S_B's business. Although H_2 still competes indirectly with H_1 for S_B's subscribers (as part of S_B's subscription–handset bundle), the elimination of direct competition for S_B's business may potentially soften the competitive pressure on H_2. Therefore, H_2 may have a tendency to set a higher wholesale price. The balance between these forces determines the intensity of handset vendor competition.

Thus, by limiting its handsets to one service provider, H_1 may in fact be able to induce H_2 to compete less aggressively. We note that if H_2's wholesale price under the exclusive regime is the same as in the nonexclusive regime (i.e., $w_2^E = w_2^{NE^{**}}$), then H_1's demand is necessarily lower than the corresponding demand in the nonexclusive regime because its supply of handsets is restricted to S_A. Thus, whether H_1 benefits from the EHA will critically depend on whether it induces H_2 to compete less aggressively. Stated differently, H_1 can be compensated for going exclusive only if it faces sufficiently lesser competitive pressure from H_2. We will refer to the change in H_2's wholesale price relative to the nonexclusive regime as the *supply price effect*. If $w_2^{E^{**}} > w_2^{NE^{**}}$, then we say that the supply price effect is positive. We next examine when the EHA is mutually beneficial.

3.3. When Does an EHA Occur?

We solve for the equilibrium of the overall game. S_A strictly benefits from H_1's EHA proposal, since $\hat{y}_A^{E^{**}} > 0$ in any EHA proposal that maximizes H_1's profits. From H_1's perspective, the supply price effect must be sufficiently high to compensate for its restricted access to the end consumer market. We find that this is possible only when H_1's handset quality is not too high, i.e., if $\delta_H \leq \delta_{1H}$, where δ_{1H} is the threshold at which H_1 is indifferent between having and not having an EHA. We will refer to δ_{1H} as the *scope for an EHA*. When H_1's handset quality is higher than δ_{1H}, S_A's market advantage from the EHA, δ_E^{**}, is higher. This imposes a downward pressure on H_2's wholesale price because its market share is more closely linked to that of S_B. In other words, a higher δ_H limits the extent by which the EHA can ease the competitive pressure on H_2, leading to a lower, and possibly negative, supply price effect. Furthermore, H_1's

profits in the nonexclusive regime are also higher, thereby requiring a larger supply price effect for the EHA to be attractive. Thus, for both reasons, an EHA occurs only if H_1's handset quality is not too high. The following proposition summarizes our findings.

Proposition 1. *An EHA occurs only when the relative quality of the exclusive handset is not too high* ($\delta_H \leq \delta_{1H}$, *where* δ_{1H} *is defined implicitly*). *The scope for an EHA* (i) *is increasing in consumers' propensity to use service* (δ_{1H} *is increasing in* α), (ii) *follows an inverted-U relation with service differentiation* (δ_{1H} *is initially increasing and then decreasing in* s), (iii) *is decreasing in handset differentiation* (δ_{1H} *is decreasing in* h), *and* (iv) *is increasing in the relative quality of the service provider with the exclusive handset* (δ_{1H} *is increasing in* δ_S).

Proof. Refer to Appendix C. □

One might have expected that EHAs are more prevalent for more attractive handsets because they can help service providers differentiate themselves. But, interestingly, our analysis shows that if a handset is more attractive in that consumers are willing to pay a significant premium for it, then an EHA may not occur: although having such a handset exclusive may be advantageous for the service provider, it may not lead to a sufficiently high supply price effect to compensate the handset vendor. Our results could explain, for instance, why Nokia and Motorola, who have traditionally been the leading vendors in many markets, have typically avoided this strategy; to the extent that their handsets commanded a higher brand premium, they were better off making their handsets nonexclusive.[22] As we discuss later in §6.1, it may also explain why Apple shifted its strategy from being exclusive. At the same time, to the extent that consumers are not willing to pay a similar premium for handsets from LG and Samsung, these handset vendors may have found EHAs more attractive.

3.3.1. Impact of Market Factors. Proposition 1 also describes how service and handset market characteristics affect the scope for an EHA. This depends on how these market factors influence the trade-off for the handset vendor. We find that the scope for an EHA is increasing in the consumers' propensity to use service (α). When α is higher, S_A's market advantage from the EHA is lower. On the one hand, this leads to a lower market share for H_1 when exclusive, making an EHA less attractive. On the other hand, it puts lesser pricing pressure on H_2 (because its market share is more closely linked to that of S_B), leading to a stronger supply price effect. We find that the latter aspect always dominates. Interestingly, the scope for an EHA follows an inverted-U relationship with service differentiation (s); S_A's market advantage follows a U-shaped relation with s, and the impact of S_A's market advantage on the supply price effect outweighs its impact on H_1's market share. We also find that the scope for an EHA is increasing in S_A's relative quality (δ_S). A higher δ_S results in a higher subscriber base for S_A, which leads to a higher market share for H_1 when exclusive but to a lower supply price effect. In this case, the former aspect dominates. Finally, the scope for an EHA is decreasing in handset differentiation (h). When h is higher, the supply price effect may be weaker because S_A's market advantage is higher and H_2's wholesale price in the nonexclusive regime is also higher to begin with. Furthermore, H_1's profits in the nonexclusive regime are higher, thereby requiring a larger supply price effect to compensate for the restricted market access. Consequently, for both reasons, the scope for an EHA is lower.

These results may explain why EHAs may be more attractive in some markets than in others. For instance, the average cellphone usage (minutes used) in the United States is considerably higher than in the United Kingdom and other western European countries (Ofcom 2009). Then, to the extent that the propensity of consumers to use wireless service is higher in the United States, this might explain why exclusive handsets are more prevalent in the United States than in these other countries and why many handsets that are exclusive in the United States are nonexclusive in these other markets.

3.4. The Value of an EHA

We found that an EHA is not mutually beneficial if the handset quality is high. Conversely, and perhaps more importantly, even if a handset's quality is low, an EHA can be mutually profitable. In particular, this is true even when $\delta_H < 0$. To understand why this is so, we examine the underlying factors that drive the value from an EHA. From the service provider's perspective, we find that an EHA always raises the rival service provider's costs; i.e., the equilibrium wholesale price differential with an EHA is always higher than without the EHA ($w_2^{E**} - w_1^{E**} > w_2^{NE**} - w_1^{NE**}$). Thus, whenever an EHA occurs, S_A benefits not only from the variety effect but also the cost-raising effect. In fact, we find that the latter always has a larger impact on S_A's profits than the former.[23] In other words, the cost-raising effect may be the main source of advantage a service provider gains from an EHA.

[22] More recently, following a significant erosion of its brand image, Motorola has started having more EHAs (see Appendix A for list of exclusive handsets in the United States in August 2011).

[23] The impact of the variety effect is the increase in S_A's profits relative to the nonexclusive regime solely because of the additional handset variety, taking the handset wholesale prices to be the same as in the nonexclusive regime. The impact of the cost-raising effect is the further increase (or decrease) in S_A's profits given the handset wholesale prices in the exclusive regime.

From the handset vendor's perspective, whenever an EHA occurs, we find that the supply price effect sufficiently eases the competitive pressure on the handset vendor such that its wholesale price when exclusive is always higher than when nonexclusive. Understandably, H_1's share of S_A's business is higher when it is exclusive because the wholesale price differential between H_2's and H_1's handset is higher. But surprisingly, we find that even H_1's overall market share can be higher when it is exclusive. Interestingly, this can occur only when H_1's relative handset quality is sufficiently low. In such instances, the wholesale price differential between the handsets increases by such an extent that the corresponding increase in H_1's share of S_A's business more than offsets the market lost by not serving S_B. The following proposition summarizes our findings.

Proposition 2. *When an EHA occurs*, (i) *it always raises the rival service provider's costs*; (ii) *the cost-raising effect has a larger impact on service provider profits than the variety effect*; (iii) *the wholesale price of the exclusive handset is always higher than without the agreement*; *and* (iv) *the exclusive handset vendor's market share may be higher than without the agreement if its relative handset quality is not too high* (*when* $s < s_1$ *or* $h > h_1$ *or* $\delta_s > \delta_{2S}$, *market share is higher if* $\delta_H \leq \delta_{2H}$, *where* $\delta_{2H} < \delta_{1H}$ *and* s_1, h_1, δ_{2S}, *and* δ_{2H} *are defined implicitly*).

Proof. Refer to Appendix C. □

Service providers have often defended their use of exclusive handsets as a means to differentiate themselves from their competitors (e.g., CTIA 2007, AT&T 2009). However, our results suggest an alternative account of why some service providers may have several exclusive handsets: even if only some of these handsets are particularly attractive to consumers, the rest may still help by raising the rival service provider's handset costs. Indeed, the main motivation for offering exclusive handsets may be to raise their rivals' costs rather than to obtain more attractive handsets. From a handset vendor's perspective, although EHAs are conventionally thought to lead to artificially low handset market share, we find that the reverse can also be true. Stated differently, not only might an EHA be profitable for a handset that would have otherwise not been popular, but in fact an EHA may increase the sales of such a handset and make it more popular. Our results suggest an interesting contrast between LG and Apple: to the extent that LG's handsets command a lower premium than Apple's, analysts may be right in blaming EHAs for Apple's low market share, while, at the same time, LG may owe its market share growth to its EHAs.[24]

[24] In practice, a service provider may also promote its exclusive handset more aggressively, and this may be another reason for higher handset market share. Our results show that even in the absence of such promotion, an EHA can increase handset market share and that this occurs when the handset quality is sufficiently low.

Table 3 How Service and Handset Characteristics Influence the Value from an EHA

	α	s	h	δ_S	δ_H
Service provider value	↑	∩ / ↓	↑	↑/∩/↓	↑
Variety effect	↓/∪/↑	↓/∪/↑	↑	↑	↑
Cost-raising effect	↑	∩ / ↓	↑	↑/∩/↓	↑
Handset vendor value	↑	∩	↓	↓/∩/↑	↓

3.4.1. Impact of Market Factors. Table 3 summarizes how service and handset market characteristics affect the value a service provider and the handset vendor gain from an EHA. It also provides a breakdown of the service provider value into the variety effect and the cost-raising effect. In the case of the value gained by a handset vendor, the impact of these market factors is essentially similar to their impact on the scope for an EHA. One exception is the impact of S_A's relative quality: when H_1's relative handset quality is sufficiently below the threshold δ_{1H}, we find that the handset vendor's value may be decreasing in δ_S. When δ_S is higher, S_A's market share is higher, which has a negative impact on the supply price effect and a positive effect on H_1's market share when exclusive. The former dominates when δ_H is sufficiently low, and hence the handset vendor's value is lower.

For the service provider, compared to the nonexclusive regime, the market advantage it gains from an EHA enables it to not only extract more surplus from consumers but also extract surplus from more consumers. Consequently, the service provider's value from an EHA depends on the interplay between three factors: the market advantage it gains from the arrangement, the value consumers derive from the service, and the extent of service differentiation. The first factor determines the number of consumers from whom the service provider can extract surplus, and all three factors determine the surplus that the service provider can extract. We find that S_A's value from the arrangement is increasing in consumers' propensity to use service (α); whereas S_A's market advantage is decreasing in α, the surplus that S_A can extract is increasing in α. Interestingly, S_A's value from the arrangement may be always increasing, or always decreasing or follow an inverted-U relation with service differentiation (s); whereas service differentiation is itself increasing in s, the value consumers derive from the service is decreasing in s and the market advantage is initially decreasing and then increasing in s. Furthermore, S_A's value from

the arrangement may be always increasing or always decreasing, or it may follow an inverted-U relation in the service provider's relative quality (δ_S). A higher δ_S leads to a higher market share for S_A, which may weaken the cost-raising effect by increasing the competitive pressure on H_2. Consequently, even though the surplus the service provider can extract is increasing in δ_S, the value from the EHA may be decreasing. We also find that the service provider's value is always increasing in handset differentiation (h) and in the exclusive handset's relative quality (δ_H) because S_A's market advantage is increasing in these factors. Table 3 also depicts how the value gained due to the variety effect and the cost-raising are affected by the market factors.

Exclusive handsets are at times seen as a means to compensate for a lack of service provider differentiation. Indeed, we do find that a service provider benefits from the variety effect of an EHA. But we also find that an EHA may be a means to leverage the service provider's existing service differentiation. The service provider's value from an EHA is higher when its horizontal and vertical service differentiations are higher. Furthermore, from Proposition 1, we note that the scope for an EHA may be increasing in the horizontal and vertical service differentiation; a higher scope allows for EHAs with better handsets, which in turn increases the service provider's value from the arrangement. Therefore, service providers may be well advised to not ignore their service dimension even as they strive to differentiate themselves from their competitors through their handsets.

4. Competitive Implications of an EHA

4.1. Impact on the Rival Service Provider and Rival Handset Vendor

As may be expected, the rival service provider is always worse off because the EHA worsens its handset variety and effectively raises its handset costs; its margins, subscriber market share, and service demand are all lower under an EHA. Because H_2's prospects are closely linked to that of S_B's, one might expect that it too is worse off. Instead, we find that H_2 is actually better off whenever an EHA occurs because, in such instances, the competition between handset vendors is less intense.

Proposition 3. *When an EHA occurs, the rival service provider is always worse off and the rival handset vendor is always better off than without the EHA.*

Proof. Refer to Appendix C. □

Our results might explain complaints against exclusive handset arrangements from the excluded service providers in the United States and in France (e.g., RCA 2008, ZDNet France 2010). Moreover, when Apple's iPhone shifted its distribution from being exclusive to nonexclusive, rival handset vendors faced increased competitive pressure and lost considerable market share to Apple at the previously excluded service providers (Lagorce 2009, NPD Group 2011). Our model predicts that this increased competitive pressure would have also forced rival handset vendors to lower their handset price to service providers. Conversely, rival handset vendors would have benefited from the reduced competitive pressure had Apple remained exclusive.

4.2. Impact on Market Prices, Service Usage, and Consumers

We find that the fixed fees of both service providers are higher when there is an EHA. S_A's fixed fees are higher both because of its higher margin and higher handset wholesale prices, and S_B's lower margin is more than offset by H_2's higher handset wholesale price. Because S_A's market share is higher with an EHA, there is more variation in usage across its subscriber base and it charges a higher usage fee than when nonexclusive. Correspondingly, S_B's service usage fee is lower when there is an EHA because its market share is lower. S_A's subscribers are worse off than without the EHA as they face strictly higher fixed and usage fees. The service usage of those consumers who switched to S_A for the exclusive handset is further negatively impacted as they subscribe to their less preferred service provider. Moreover, we find that all of S_B's subscribers are also worse off; although these consumers benefit from the lower service usage fee, this is more than offset by the disutility from higher fixed fees and reduced choice of handsets. Finally, we find that the average service usage across subscribers is always lower.

Proposition 4. *When an EHA occurs* (i) *service–handset subscription fees are higher than without the EHA*, (ii) *the service usage fee for the exclusive handset service provider* (*excluded service provider*) *is higher* (*lower*) *than without the EHA*, *and* (iii) *average service usage is lower and all consumers are worse off than without the EHA.*

Proof. Refer to Appendix C. □

One might think that an EHA only affects consumers who could not switch service providers for a desired handset and those who switched to a less preferred service provider for an exclusive handset. But we find that even those who did not have to switch service providers for the exclusive handset and those who would not have bought the handset had it been nonexclusive may also be negatively impacted. Thus, a larger group of consumers may be adversely affected than it may have initially seemed. Our results cast doubts on the arguments of the French Supreme

Court that the availability of competing phones for the excluded service providers should allay anticompetitive concerns.

4.3. Impact on Handset Innovation

Proponents of wireless network neutrality (WNN) have argued that EHAs may hinder handset innovation (e.g., Wu 2007, Frieden 2009). To shed light on this issue, we compare H_1's incentive to improve its relative handset quality (δ_H) under the exclusive and nonexclusive regimes in instances where an EHA occurs. As we show in Lemma 6 in Appendix B, we have that

$$\frac{d\Pi_{H_1}^{C^{**}}}{d\delta_H} = (D_{A1}^{C^{**}} + D_{B1}^{C^{**}})\left(1 + \frac{\partial w_2^{C^{**}}}{\partial \delta_H}\right), \tag{22}$$

where $C \in \{E, NE\}$ is the distribution regime. Thus, an increase in the relative quality of H_1's handset can be thought of as having two effects—namely, (i) a *market share effect*, as denoted by $D_{A1}^{C^{**}} + D_{B1}^{C^{**}}$; and (ii) a *competitive response effect*, as denoted by $\partial w_2^{C^{**}}/\partial \delta_H$.[25] The larger H_1's market share, the more valuable the increase in handset quality, because this is leveraged over a larger base of customers. The larger the (magnitude of the) competitive response, the less valuable the increase in handset quality, because this limits H_1's ability to capture the value created by higher handset quality. We find that in instances where an EHA occurs, the competitive response effect is higher under the exclusive regime than under the nonexclusive regime. We find that the competitive response effect offsets the market share effect when H_1's market share is higher under the exclusive regime, and the two reinforce each other when H_1's market share is lower under the exclusive regime. Consequently, H_1's incentive to improve its handset quality is always lower than under the nonexclusive regime.

Proposition 5. *When an EHA occurs, the exclusive handset vendor's incentive to improve its handset quality is lower than under the nonexclusive regime.*

Proof. Refer to Appendix C. □

Our results support the perspective of WNN proponents regarding handset innovation. An EHA may limit both the market base over which a handset vendor can leverage its innovation and the value that can be captured owing to the rival's reaction.

5. Extensions

To gain further insights, we examine three separate extensions to our basic model. We discuss here only the key results. The details can be found in the online electronic companion. Furthermore, in §§F–J of the online electronic companion, we show that our main results are robust to the following extensions: (i) when consumers make service–handset choices simultaneously, (ii) when service usage is higher with higher quality handsets (such that handset choice affects service usage), (iii) when H_1 is a Stackelberg price leader with respect to H_2 in the nonexclusive and exclusive regimes, (iv) when there is a third competing handset vendor (such that S_B is not dependent only on H_2 in the exclusive regime), and (v) when service providers offer service plans with unlimited minutes.[26]

5.1. With Which Service Provider to Tie In

In §A of the online electronic companion, we consider that H_1 can choose a service provider to negotiate an EHA. We find that whereas H_1's market share is higher if it ties in with the better service provider, an arrangement with the poorer service provider eases the competitive pressure on H_2 to a greater extent, leading to a higher supply price effect. Interestingly, the latter aspect may dominate in some instances, and it may be more profitable for a handset vendor to tie in with the poorer service provider. Thus, a handset vendor may actually prefer not to tie in with the better service provider. For instance, in the United States, Verizon is considered to be the better service provider with regard to overall network quality (e.g., *Consumer Reports* 2009) compared with its rivals. Yet one observes that other service providers also have many exclusive handsets. We also find that the scope for an EHA is higher for the better service provider, which suggests that the better service provider is likely to have better exclusive handsets. In §B of the online electronic companion, we examine an alternative process for the choice of service provider, whereby service providers may make competing proposals to H_1 for an EHA. We find that the results are qualitatively similar to before in the following sense: the service provider that would have been more attractive for H_1 to negotiate an arrangement is the one that makes the better competing offer.[27]

5.2. Use of Side Payments

In §C of the online electronic companion, we consider that H_1 and S_A may use a side payment to share the surplus from an EHA and follow a Nash bargaining process to determine the terms of the arrangement. In this case, whenever the negotiation

[25] We note that $\partial w_2^{C^{**}}/\partial \delta_H < 0$.

[26] For all extensions, we impose parameter restrictions as needed to ensure that a pure-strategy equilibrium exists. Refer to the individual sections in the online electronic companion for details.

[27] When service providers can make competing proposals that include a side payment, we then find that only the better service provider may make the winning proposal. Refer to §B of the online electronic companion.

Table 4 Joint Value from an EHA When Side Payments Are Used

	α	s	h	δ_S	δ_H
Joint value	↑	⌒	↓	↓ / ⌒ / ↑	↓

is successful, the handset wholesale price under the exclusive regime is set to maximize the joint profits of H_1 and S_A, and their relative bargaining power determines how the surplus is shared. We find that the side payment is always from the service provider to the handset vendor. In practice, this may be in the form of the service provider sharing product development or promotional expenses. We find that the scope for an EHA may be higher or lower than without side payments. On the one hand, side payments allow the transfer of some of the service provider's surplus to the handset vendor, which can increase the scope. On the other hand, H_1's wholesale price is lower (as it is set to maximize joint profits), intensifying the competitive pressure on H_2 and lowering the supply price effect, which can decrease the scope. Table 4 shows how the joint value from an EHA is affected by market factors.

5.3. Equilibrium Industry Structure

In §D of the online electronic companion, we examine the equilibrium industry structure when the service providers are symmetric and H_1 can negotiate an EHA with S_A, and H_2 with S_B.[28] In particular, this allows us to evaluate the French Supreme Court's argument that if excluded service providers can form EHAs with other handset vendors, then there would be no cumulative anticompetitive effects. We find that when the difference in handset qualities is sufficiently high, only the poorer handset vendor may form an EHA, and our earlier results continue to hold. Whereas when the difference in handset quality is not too high, both handset vendors may form EHAs. Average service usage is lower than in the nonexclusive regime but higher than when only S_A could form an arrangement. Handset prices and up-front subscription fees are, however, higher than when only S_A could form an arrangement. Once again, our results cast doubts on the arguments of the French Supreme Court.

6. Discussion and Conclusion

6.1. Managerial Implications

6.1.1. Handset Vendor's Perspective. For a handset vendor, an EHA can be a means to induce its rival to compete less aggressively by limiting the availability of its handsets. Such a strategy may be profitable only when the handset is not too attractive to consumers relative to competing handsets. Moreover, a handset vendor's market share can actually be higher when it is exclusive if the handset is not too attractive; otherwise, its market share is lower when exclusive.

The shift in Apple's distribution strategy for the iPhone from initially being exclusive to later being nonexclusive provides an interesting context to understand our results. Apple was new to the handset market when it launched the iPhone, and its reputation as a handset vendor had not been established. In fact, its earlier attempt to enter the handset market through a partnership with Motorola had failed (AT&T 2009). Thus, to the extent that Apple may have been unsure about how attractive the iPhone would be to consumers, our analysis suggests that an exclusive strategy may have been sensible. However, since the launch, Apple's reputation grew and became more certain. Furthermore, Apple has substantially improved the iPhone's features and created a significant franchise of third-party applications, all of which made the iPhone more attractive to consumers. Consequently, an exclusive strategy would have become less attractive. Indeed, industry analysts believed that, by remaining exclusive, Apple was keeping its market share artificially low and leaving money on the table (Elmer-Dewitt 2009a, b; Savitz 2009). When the iPhone eventually became nonexclusive, rival handset vendors faced increased competitive pressure and lost considerable market share to Apple at the previously excluded service providers (Lagorce 2009, NPD Group 2011). Our model predicts that this increased competitive pressure would have forced rival handset vendors to also lower their handset prices to service providers. Conversely, had Apple remained exclusive, these rival handset vendors would have benefited from the reduced competitive pressure.

6.1.2. Service Provider's Perspective. The conventional perspective that EHAs are primarily meant to help service providers differentiate themselves from their competitors may overlook several aspects. First, if a handset is very attractive to consumers, then the handset vendor may not find it profitable to have an EHA. Thus, a service provider may be restricted in how attractive its exclusive handsets can be. Second, an EHA may also be a means to raise a rival service provider's handset costs by limiting the handsets available to the rival. In fact, this may be a bigger source of advantage than differentiation through handset variety. Consequently, our findings suggest that even if an exclusive handset is relatively less attractive than competing handsets, the service provider may nevertheless benefit from the cost-raising effect. Indeed, this may be the reason why

[28] By considering symmetric service providers, we abstract away from the process by which a handset vendor is matched with a service provider.

some service providers may have several exclusive handsets; although only some of them may be particularly attractive, the rest may still help raise the rival's costs. Finally, even as service providers strive to differentiate themselves through handsets, we find that they may be well advised not to ignore their service dimension. A service provider may have to be sufficiently differentiated to tie in with more attractive handsets. Also, the service provider's value from an EHA may be higher if its service differentiation is higher. Thus, our results provide a broader perspective on how service providers can leverage and benefit from exclusive handsets.

6.2. Policy Implications

Although our results support concerns regarding potential anticompetitive impact of EHAs, others have argued against such effects. The French Supreme Court held that exclusive handsets were not anticompetitive because competing handsets were still available to the excluded service providers (ZDNet France 2010). The court further stated that it did not expect cumulative anticompetitive effects if the excluded service providers could form EHAs of their own. Critics of WNN have likened EHAs to other forms of vertical restraints seen in other industries and argue that these restrictions facilitate coordination between service providers and handset vendors, thereby improving market efficiency that ultimately benefits consumers. Specifically, Hahn et al. (2007) and Ehrlich et al. (2010) argue that, similar to exclusive dealerships, handset exclusivity encourages the service provider to promote the handset aggressively, whereas, without exclusivity, a service provider may be concerned about rivals free riding on its handset promotion efforts. Ehrlich et al. (2010) and Faulhaber et al. (2012) argue that handset exclusivity reduces the product development risk for handset vendors by encouraging a service provider to make sufficient up-front purchase commitments. Hahn et al. (2007) and Ehrlich et al. (2010) also argue that because the handset vendor typically "freely" agrees to exclusivity, this must imply that EHAs can only be for efficiency reasons and must create incentives for handset innovation.

Although our model does not capture the potential sources of efficiency identified above, it highlights sources of inefficiency that may have been overlooked. Unlike in the case of an exclusive dealership for a stand-alone product, an exclusive handset is bundled along with service from a particular service provider. Then, to the extent that consumers are heterogeneous in their preferences for handsets and service, such an arrangement (a) distorts consumers' choices of handset, service provider, and service usage; and (b) significantly limits the handset vendor's access to end consumers, which distorts competition. In this context our analysis shows that, even when competing handsets are available to the excluded service providers, an EHA may not only lead to higher service and handset prices, which lower consumer welfare and market efficiency, but may also reduce the exclusive handset vendor's incentive to improve its handset quality—despite competing handsets being available to the excluded service providers. Moreover, it may in fact be the market inefficiencies created by the EHA that motivate the handset vendor to freely agree to the arrangement. Furthermore, when the excluded service provider can form an EHA of its own, the anticompetitive effects may persist and even worsen. Our results thus support concerns raised by the proponents of WNN.

6.3. Relevance to Other Industries

Our findings may be of interest to firms in other industries that have similar exclusive arrangements in competitive contexts, whereby one firm (corresponding to the handset vendor) agrees to make its offering available exclusively with that of another firm (corresponding to the service provider), but not vice versa. For instance, retailers may have exclusive merchandise agreements with national brand manufacturers, videogame console makers may have exclusive third-party video games, and satellite and cable network companies may have exclusive content providers. We note that some of our assumptions may not readily extend to other industry settings. We assumed that one firm provides a product while the other provides a service. We do not, however, expect that this influenced the nature of the strategic interactions per se. We further assumed that consumers follow a sequential decision process. But we relaxed this assumption in §F of the online electronic companion and found that our main insights continue to hold qualitatively, and may even be stronger. We also assumed that the firms providing complementary offerings are engaged in a vertical relationship. In particular, handset vendors were Stackelberg price leaders to the service providers. Alternative game structures may apply in other industry settings, which may influence the strength of the supply price effect and the cost-raising effect. For instance, they may be weaker if prices of complementary components are set simultaneously. Finally, there may be other industry-specific factors that our model does not capture. We leave it for future research to examine these issues.

6.4. Limitations and Future Research

Although our analysis provides a competitive rationale for an EHA, an alternative explanation could

be that an unfamiliar handset brand may utilize exclusive distribution through a reputable service provider to build market awareness and reputation. For instance, this may be relevant for foreign brands such as LG and Samsung in the U.S. market. As such, we cannot rule out this alternative explanation, and further empirical analysis may be necessary to distinguish between these drivers.[29]

Because network capacity investments are typically lumpy and are of the fixed-cost variety, we assumed that service providers do not face any marginal costs of providing service. But in some instances, a service provider may lease additional capacity and incur a variable cost. In §K of the online electronic companion, we show that our results continue to hold qualitatively if service providers face a constant marginal cost of providing service. Service providers may also face network congestion because of capacity constraints, which may degrade the quality of their service. Future research may examine how EHAs affect service provider network quality and investments in network infrastructure.

We assumed the locations of the handset vendors (along the y dimension) to be exogenous. As is known from previous research (e.g., d'Aspremont et al. 1979), a Hotelling-line setup, such as ours, with linear transportation costs is not well suited to analyze optimal location decisions, because a pure-strategy price equilibrium does not exist for a range of firm locations. Nevertheless, in §L of the online electronic companion, we conduct some limited analysis by considering that each handset vendor may choose between two locations. We find that it is a dominant strategy for handset vendors to locate closer to each other, and our main insights continue to hold qualitatively. We do note that the location outcome is likely to be sensitive to our assumption of linear transportation costs.[30] It is beyond the scope of our current work to consider nonlinear transportation costs.

Electronic Companion

An electronic companion to this paper is available as part of the online version at http://dx.doi.org/10.1287/mksc.1120.0752.

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Appendix A. Data Collected by Authors for Table 1 in §1

We identified the handsets available from the four largest U.S. service providers (as of August 7, 2011) from their websites. We focused on the smartphone category because this accounted for a majority of the handsets currently offered. We considered only handsets from major handset vendors: Apple, HTC, HP/Palm, LG, Motorola, Nokia, RIM, Samsung, and Sony Ericsson. We used service provider press releases to identify handsets launched exclusively. Additionally, Verizon identifies its exclusive handsets as "exclusively available through Verizon Wireless" on its website (http://www.verizonwireless.com; accessed August 2011). Table A.1 summarizes these data.

Only handsets that were launched exclusively and remained exclusive for at least six months were considered to be exclusive launches. Four such exclusive handsets later became nonexclusive and are indicated by a superscript a in Table A.1. For example, the iPhone 4G was launched exclusively by AT&T in June 2010 and became available from Verizon in February 2011. In some cases, we collected some additional information to determine whether a handset could be considered exclusive. For example, the iPhone 3GS, which is sold exclusively, was succeeded by the iPhone 4G, which is currently not sold exclusively. But we found that the iPhone 3GS continues to be a top-selling model even more than a year after the iPhone 4 was released. Another example is that product reviews described the Motorola XPRT as Sprint's version of the Motorola Droid Pro that was exclusively launched from Verizon. So we concluded that Verizon's exclusivity agreement had concluded.

Although it is not straightforward to objectively determine to what extent a handset model is simply a branded variant or is meant to address an underlying market need, we devised some criteria to ascertain whether an exclusive handset had a "close" variant available through another service provider at the time of launch or within six months following its launch. We used online product reviews and comparisons from two leading handset review websites, CNET.com and Engadget.com, to judge how close an exclusive handset was to other handsets from the same handset vendor available from other service providers. We also collected information about how the handset vendor distributed its handsets in another market; we chose the United Kingdom because information was more easily available for this market. If a handset vendor offered comparable models exclusively through different service providers in the United States but offered similar comparable models nonexclusively in the United Kingdom market, then we deemed that it is valuable for the handset vendor to provide this variety to end consumers. For instance, from product reviews we found that Samsung's Fascinate (Verizon), Captivate (AT&T), Epic 4G (Sprint), and Vibrant (T-Mobile) were all variants of the Samsung's Galaxy S handset.

[29] We do note that LG and Samsung entered the U.S. market more than a decade ago and have had a substantial market presence in recent years.

[30] D'Aspremont et al. (1979) show that firms may locate farther away from each other when the transportation cost is quadratic.

Table A.1 Data Used in Table 1 in §1

Manufacturer	Exclusive	Nonexclusive
	AT&T	
Apple	iPhone 3GS, iPhone 4G[a]	
HP/Palm	Veer 4G	Palm Pixi
HTC	Status, 7 Surround,[a] Inspire 4G[b]	HD7S
LG	Quantum, Thrill 4G	Phoenix
Motorola	Atrix	Flipside
RIM	Torch	Pearl, Curve
Samsung	Focus, Infuse 4G[b]	Captivate
Sony Ericsson		Xperia Play
	Verizon	
Apple		iPhone 4G
HP/Palm		Pre 2
HTC	Droid Incredible 2, Thunderbolt 4G[b]	Trophy 7
LG		Fathom, Vortex, Revolution
Motorola	Citrus, Droid 3, Droid Pro,[a] Droid 2 Global,[b] Droid X2,[b]	
RIM	Storm 2	Bold 9930, Curve
Samsung	Fascinate,[b] Continuum,[b]	Droid Charge
Sony Ericsson		Xperia Play
	Sprint	
HP/Palm		Palm Pixi
HTC	Evo 4G, Evo Shift 4G, Evo 3D	Arrive
LG		Optimus S
Motorola		XPRT, Photon 4G
RIM		Bold 9930, Tour, Curve
Samsung		Epic 4G, Transform
	T-Mobile	
HTC	Sensation 4G, HD 7[a]	Wildfire
LG		Optimus T
Motorola	Cliq, Defy[b]	
RIM		Bold 9780, Curve
Samsung	Exhibiti 4G, Gravity Smart, Galaxy S 4G[b]	Vibrant, Dart

Source. Service provider websites and press releases.

[a]Became nonexclusive after six or more months following launch.

[b]A close variant was available from another service provider (within six months of launch).

Furthermore, in the United Kingdom, we found that Samsung offered only one version of the Galaxy S to all service providers. Therefore, we concluded that the handset models in the United States were close variants. In contrast, although HTC's Droid Incredible (Verizon) and Inspire 4G (AT&T) are both Android-based smartphones, we found from product reviews that they were, respectively, based on HTC's Incredible S and Desire HD handsets. Furthermore, both of these models were available nonexclusively from all service providers in the United Kingdom. Thus, we concluded that the Incredible S and Desire HD were distinct variants, and the Droid Incredible did not have a close variant; we concluded, however, that Inspire 4G did because Thunderbolt 4G (Verizon) was also based on the Desire HD handset. Based on this approach, we concluded that 9 of the 32 exclusive handsets were "close variants." These are indicated by a superscript b in Table A.1.

Appendix B. Lemmas in §§3 and 4

Lemma 1. *When H_1 is nonexclusive, given the handset wholesale prices, the equilibrium service provider prices are given by*

$$F_{Aj}^{NE^*} = w_j^{NE} + \frac{1}{8}s(4\alpha - 3s)\left(3 - \frac{2}{8\alpha - 5s}\delta_S\right)\hat{x}^{NE^*},$$

$$p_A^{NE^*} = \frac{1}{2}s\hat{x}^{NE^*},$$

$$F_{Bj}^{NE^*} = w_j^{NE} + \frac{1}{8}s(4\alpha - 3s)\left(3 + \frac{2}{8\alpha - 5s}\delta_S\right)(1 - \hat{x}^{NE^*}),$$

$$p_B^{NE^*} = \frac{1}{2}s(1 - \hat{x}^{NE^*}),$$

where $j \in \{1, 2\}$. The equilibrium service provdier profits are given by

$$\Pi_{S_A}^{NE^*} = \frac{1}{8}s\left(16\alpha - 11s + \frac{4(2\alpha - s)}{3(8\alpha - 5s)}\delta_S\right)(\hat{x}^{NE^*})^2,$$

$$\Pi_{S_B}^{NE^*} = \frac{1}{8}s\left(16\alpha - 11s - \frac{4(2\alpha - s)}{3(8\alpha - 5s)}\delta_S\right)(1 - \hat{x}^{NE^*})^2.$$

S_A's equilibrium subscription market share given by

$$\hat{x}^{NE^*} = \frac{1}{2} + \frac{2(2\alpha - s)}{3s(8\alpha - 5s)}\delta_S.$$

H_1's equilibrium market shares of each service provider's subscribers are given by

$$\hat{y}_A^{NE^*} = \hat{y}_B^{NE^*} = \frac{h + \delta_H + w_2^{NE} - w_1^{NE}}{2h}.$$

Proof. Substituting for F_{Aj}^{NE} in terms of $\hat{x}^{NE}$ and $\hat{y}_A^{NE}$ from (9) and (11), S_A's profits are given by

$$\begin{aligned}\Pi_{S_A}^{NE} = \hat{x}^{NE}\Bigg[&\left(\alpha + \frac{1}{2}\delta_S - \frac{1}{2}s\hat{x}^{NE} - p_A^{NE}\right)p_A^{NE} + (2\alpha - s - p_A^{NE} - p_B^{NE}) \\ &\cdot\left(\frac{s + \delta_S + p_B^{NE} - p_A^{NE}}{2} - s\hat{x}^{NE}\right) \\ &+ \hat{y}_A^{NE}(h + \delta_H - h\hat{y}_A^{NE} + w_2^{NE} - w_1^{NE}) \\ &- h\left(\frac{h + \delta_H + F_{B2}^{NE} - F_{B1}^{NE}}{2h}\right)^2 + F_{B2}^{NE} - w_2^{NE}\Bigg]. \quad \text{(B1)}\end{aligned}$$

$\Pi_{S_A}^{NE}$ is concave in p_A^{NE}, $\hat{y}_A^{NE}$, and $\hat{x}^{NE}$. In equilibrium, we require

$$\frac{d\Pi_{S_A}^{NE}}{dp_A^{NE}} = 0 \implies p_A^{NE^*} = \frac{1}{2}s\hat{x}^{NE^*}, \quad \text{(B2)}$$

$$\frac{d\Pi_{S_A}^{NE}}{d\hat{y}_A^{NE}} = 0 \implies \hat{y}_A^{NE^*} = \frac{h + \delta_H + w_2^{NE} - w_1^{NE}}{2h}, \quad \text{(B3)}$$

$$\frac{d\Pi_{S_A}^{NE}}{d\hat{x}_A^{NE}} = 0$$

$$\begin{aligned}\implies F_{B2}^{NE^*} = {}& s(4\alpha - 2s - p_A^{NE^*} - 2p_B^{NE^*})\hat{x}^{NE^*} \\ &- \left(\alpha + \frac{1}{2}\delta_S - p_A^{NE^*}\right)p_A^{NE^*} - (2\alpha - s - p_A^{NE^*} - p_B^{NE^*}) \\ &\cdot\frac{s + \delta_S + p_B^{NE^*} - p_A^{NE^*}}{2} + h\left(\frac{h + \delta_H + F_{B2}^{NE^*} - F_{B1}^{NE^*}}{2h}\right)^2 \\ &- \hat{y}_A^{NE}(h + \delta_H - h\hat{y}_A^{NE^*} + w_2^{NE} - w_1^{NE}) + w_2^{NE}. \quad \text{(B4)}\end{aligned}$$

Similarly, substituting for F_{B1}^{NE} and F_{B2}^{NE} in $\Pi_{S_B}^{NE}$ and optimizing, we have that, in equilibrium,

$$p_B^{NE^*} = \frac{1}{2}s(1-\hat{x}^{NE^*}), \quad \hat{y}_B^{NE^*} = \frac{h+\delta_H+w_2^{NE}-w_1^{NE}}{2h}, \tag{B5}$$

$$\begin{aligned} F_{A2}^{NE^*} &= s(4\alpha-2s-2p_A^{NE^*}-p_B^{NE^*})(1-\hat{x}^{NE^*}) \\ &\quad -\left(\alpha-\frac{1}{2}\delta_S-p_B^{NE^*}\right)p_B^{NE^*}-(2\alpha-s-p_A^{NE^*}-p_B^{NE^*}) \\ &\quad \cdot\frac{s-\delta_S+p_A^{NE^*}-p_B^{NE^*}}{2}+h\left(\frac{h+\delta_H+F_{A2}^{NE^*}-F_{A1}^{NE^*}}{2h}\right)^2 \\ &\quad -\hat{y}_B^{NE^*}(h+\delta_H-h\hat{y}_B^{NE^*}+w_2^{NE}-w_1^{NE})+w_2^{NE}. \end{aligned} \tag{B6}$$

Substituting in (11) for $F_{i1}^{NE^*}$ from (9), and $F_{i2}^{NE^*}$, $p_i^{NE^*}$, and $\hat{y}_i^{NE^*}$ from (B2) to (B6), we obtain

$$\begin{aligned} &4\delta_S(2\alpha-s)-3s(2\hat{x}^{NE^*}-1)(8\alpha-5s)=0 \\ &\quad\Longrightarrow\quad \hat{x}^{NE^*}=\frac{1}{2}+\frac{2(2\alpha-s)}{3s(8\alpha-5s)}\delta_S. \end{aligned} \tag{B7}$$

Substituting back for $\hat{x}^{NE^*}$, we obtain the desired results. □

Lemma 2. *When H_1 is nonexclusive, the equilibrium handset vendor prices are given by*

$$w_1^{NE^{**}} = h+\tfrac{1}{3}\delta_H, \quad w_2^{NE^{**}} = h-\tfrac{1}{3}\delta_H.$$

Their equilibrium profits are given by

$$\Pi_{H_1}^{NE^{**}} = \frac{(3h+\delta_H)^2}{18h}, \quad \Pi_{H_2}^{NE^{**}} = \frac{(3h-\delta_H)^2}{18h}.$$

H_1's equilibrium market shares of each service provider's subscribers are given by

$$\hat{y}_A^{NE^{**}} = \hat{y}_B^{NE^{**}} = \frac{3h+\delta_H}{6h}.$$

Proof. We obtain derived demand for handsets from Lemma 1. Handset vendor profits are given by

$$\begin{aligned} \Pi_{H_1}^{NE^*} &= w_1^{NE}\left(\frac{h+\delta_H+w_2^{NE}-w_1^{NE}}{2h}\right), \\ \Pi_{H_2}^{NE^*} &= w_2^{NE}\left(\frac{h-\delta_H+w_1^{NE}-w_2^{NE}}{2h}\right). \end{aligned} \tag{B8}$$

Solving for the equilibrium wholesale price strategies, we obtain the desired results. □

Lemma 3. *When H_1 is exclusive, given handset wholesale prices, the equilibrium service provider prices are given by*

$$F_{Aj}^{E^*} = w_j^E+\frac{1}{8}s\left[(4\alpha-3s)\left(3-\frac{2}{8\alpha-5s}\delta_S\right)+6s\delta_E^*\right]\hat{x}^{E^*},$$

$$F_{B2}^{E^*} = w_2^E+\frac{1}{8}s\left[(4\alpha-3s)\left(3+\frac{2}{8\alpha-5s}\delta_S\right)-6s\delta_E^*\right](1-\hat{x}^{E^*}),$$

$$p_A^{E^*} = \tfrac{1}{2}s\hat{x}^{E^*}, \quad p_B^{E^*} = \tfrac{1}{2}s(1-\hat{x}^{E^*}),$$

where $j\in\{1,2\}$, $\delta_E^* = (4/(3s(8\alpha-5s)))h(\hat{y}_A^{E^*})^2$. The equilibrium service provider profits are given by

$$\Pi_{S_A}^{E^*} = \frac{1}{8}s\left(16\alpha-11s+\frac{4(2\alpha-s)}{3(8\alpha-5s)}\delta_S+2s\delta_E^*\right)(\hat{x}^{E^*})^2,$$

$$\Pi_{S_B}^{E^*} = \frac{1}{8}s\left(16\alpha-11s-\frac{4(2\alpha-s)}{3(8\alpha-5s)}\delta_S-2s\delta_E^*\right)(1-\hat{x}^{E^*})^2.$$

S_A's equilibrium subscription market share given by

$$\hat{x}^{E^*} = \frac{1}{2}+\frac{2(2\alpha-s)}{3s(8\alpha-5s)}\delta_S+\delta_E^*.$$

H_1's equilibrium market share is given by

$$\hat{y}_A^{E^*} = \frac{h+\delta_H+w_2^E-w_1^E}{2h}.$$

Proof. From (17) and (19), we have

$$\begin{aligned} \Pi_{S_A}^E &= \hat{x}^E\left(\left(\alpha+\frac{1}{2}\delta_S-\frac{1}{2}s\hat{x}^E-p_A^E\right)p_A^E+(2\alpha-s-p_A^E-p_B^E)\right. \\ &\quad \left.\cdot\left(\frac{s+\delta_S+p_B^E-p_A^E}{2}-s\hat{x}^E\right)\right) \\ &\quad +\hat{x}^E(\hat{y}_A^E(h+\delta_H-h\hat{y}_A^E+w_2^E-w_1^E)+F_{B2}^E-w_2^E), \end{aligned} \tag{B9}$$

$$\begin{aligned} \Pi_{S_B}^E &= (1-\hat{x}^E)\left(\left(\alpha-\frac{1}{2}\delta_S-\frac{1}{2}s(1-\hat{x}^E)-p_B^E\right)p_B^E\right. \\ &\quad +(2\alpha-s-p_A^E-p_B^E) \\ &\quad \left.\cdot\left(\frac{s-\delta_S+p_A^E-p_B^E}{2}-s(1-\hat{x}^E)\right)\right) \\ &\quad +(1-\hat{x}^E)\left(F_{A2}^E-w_2^E-h\left(\frac{h+\delta_H+F_{A2}^E-F_{A1}^E}{2h}\right)^2\right). \end{aligned} \tag{B10}$$

We then proceed as in Lemma 1 to obtain the desired results. □

Lemma 4. *When H_1 is exclusive, the equilibrium handset vendor prices are given by*

$$w_1^{E^{**}} = \frac{1}{2}\left(\frac{12h^2s(8\alpha-5s)}{6d^2+3hs(8\alpha-5s)+4h(2\alpha-s)\delta_S}+d+h+\delta_H\right),$$

$$w_2^{E^{**}} = \frac{1}{2}\left(\frac{12h^2s(8\alpha-5s)}{6d^2+3hs(8\alpha-5s)+4h(2\alpha-s)\delta_S}-d-h-\delta_H\right),$$

where d is the real root of the following cubic equation:

$$\begin{aligned} &10d^3+6d^2(h+\delta_H)+3dh(3(8\alpha-5s)s+4(2\alpha-s)\delta_S) \\ &\quad +3hs(8\alpha-5s)(5h+\delta_H)+4h(2\alpha-s)(h+\delta_H)\delta_S=0. \end{aligned}$$

Proof. We first construct an equilibrium where both service providers sell H_2's handset and then rule out an equilibrium where only S_B sells H_2's handset. From Lemma 3, the handset vendor profit functions are given by

$$\begin{aligned} \Pi_{H_1}^{E^*} &= w_1^E\left[\frac{1}{2}+\frac{2(2\alpha-s)}{3s(8\alpha-5s)}\delta_S+\frac{4h}{3s(8\alpha-5s)}\right. \\ &\quad \left.\cdot\left(\frac{h+\delta_H+w_2^E-w_1^E}{2h}\right)^2\right] \\ &\quad \cdot\left(\frac{h+\delta_H+w_2^E-w_1^E}{2h}\right), \end{aligned} \tag{B11}$$

$$\begin{aligned} \Pi_{H_2}^{E^*} &= w_2^E\left(1-\left[\frac{1}{2}+\frac{2(2\alpha-s)}{3s(8\alpha-5s)}\delta_S+\frac{4h}{3s(8\alpha-5s)}\right.\right. \\ &\quad \left.\left.\cdot\left(\frac{h+\delta_H+w_2^E-w_1^E}{2h}\right)^2\right]\right. \\ &\quad \left.\cdot\left(\frac{h+\delta_H+w_2^E-w_1^E}{2h}\right)\right). \end{aligned} \tag{B12}$$

In equilibrium, the following first-order conditions must hold:

$$\frac{d\Pi_{H_1}^{E^*}}{dw_1^E}=0, \quad \frac{d\Pi_{H_2}^{E^*}}{dw_2^E}=0. \tag{B13}$$

These are nonlinear simultaneous polynomial equations in $w_1^{E^{**}}$ and $w_2^{E^{**}}$. To solve these equations, we use the following change of variables:

$$w_1^{E^{**}}=\frac{t+d+h+\delta_H}{2}, \quad w_2^{E^{**}}=\frac{t-d-h-\delta_H}{2}. \tag{B14}$$

Substituting in (B13) and rearranging, we obtain

$$\frac{d\Pi_{H_1}^{E^*}}{dw_1^E}-\frac{d\Pi_{H2}^{E^*}}{dw_2^E}=0, \tag{B15}$$

$$\begin{aligned}\Longrightarrow \quad & 10d^3-6d^2(h+\delta_H)+3dh(8\alpha s-15s^2+24\alpha\delta_S-4s\delta_S)\\ & +3hs(8\alpha-5s)+4h(2\alpha-s)\delta_S=0,\end{aligned} \tag{B16}$$

which is a cubic equation involving only d. It is tedious to show by hand (using Descartes' sign rule) but can be easily verified using analytical software such as Mathematica that, given our parameter range, this equation has one real root.[31] We also have that

$$\begin{aligned}&\frac{d\Pi_{H_1}^{E^*}}{dw_1^E}+\frac{d\Pi_{H2}^{E^*}}{dw_2^E}=0\\ &\Longrightarrow \quad t=\frac{12h^2s(8\alpha-5s)}{6d^2+3hs(8\alpha-5s)+4h(2\alpha-s)\delta_S}.\end{aligned} \tag{B17}$$

Thus, there is a unique candidate for an equilibrium where both service providers sell H_2's handset. We verify numerically that this candidate satisfies the requisite boundary conditions for an internal solution (market shares are positive and wholesale prices are positive).[32] We further verify numerically that, given $w_1^{E^{**}}$, it is not profitable for H_2 to set its wholesale price such that $\hat{y}_{S_A}^{E^*}=0$, and it serves only S_B. Therefore, there is a unique equilibrium where H_2 serves both service providers.

Now suppose, toward a contradiction, there exists an equilibrium where the wholesale prices are such that S_A does not find it worthwhile to sell H_2's handset. We will use the superscript *EE* to denote the variables in this scenario. Lemma 7 provides the service providers' subgame equilibrium strategies for this scenario. The handset vendor profits are given by

$$\Pi_{H_1}^{EE^*}=w_1^{EE}\left[\frac{1}{2}+\frac{2(2\alpha-s)}{3s(8\alpha-5s)}\delta_S+\frac{4(w_2^{EE}-w_1^{EE}+\delta_H)}{3s(8\alpha-5s)}\right], \tag{B18}$$

$$\Pi_{H_2}^{EE^*}=w_2^{EE}\left[\frac{1}{2}-\frac{2(2\alpha-s)}{3s(8\alpha-5s)}\delta_S-\frac{4(w_2^{EE}-w_1^{EE}+\delta_H)}{3s(8\alpha-5s)}\right]. \tag{B19}$$

[31] Mathematica uses advanced methods from computational algebra such as a Gröbner basis to manipulate polynomial expressions that are difficult to mimic manually.

[32] We note that given α, all other parameters in the model are bounded. Furthermore, the model can be normalized with respect to α by scaling s and δ_S with respect to α, and h and δ_H with respect to α^2. Thus, the entire parameter space can effectively be spanned numerically. And, if our results hold for, say, $\alpha=1$, then they can be extended to any α.

Solving for the equilibrium wholesale prices, we have

$$\begin{aligned}w_1^{EE^{**}}&=\frac{3s(8\alpha-5s)}{8}+\frac{2\alpha-s}{6}\delta_S+\frac{\delta_H}{3},\\ w_1^{EE^{**}}&=\frac{3s(8\alpha-5s)}{8}-\frac{2\alpha-s}{6}\delta_S-\frac{\delta_H}{3}.\end{aligned} \tag{B20}$$

However, at these wholesale prices, S_A will sell H_2's handsets, which is a contradiction. □

Lemma 5. *H_1's derived demand is more elastic in the exclusive regime than in the nonexclusive regime.*

Proof. H_1's derived demand in the nonexclusive regime is given by

$$D_{A1}^{NE^*}+D_{B1}^{NE^*}=\frac{h+\delta_H+w_2^{NE}-w_1^{NE}}{2h}, \tag{B21}$$

and demand elasticity is given by

$$\eta_1^{NE}=-\frac{1}{2h}\frac{w_1^{NE}}{(h+\delta_H+w_2^{NE}-w_1^{NE})/(2h)}. \tag{B22}$$

H_1's derived demand in the exclusive regime is given by

$$\begin{aligned}\hat{x}^{E^*}D_{A1}^{E^*}=&\left(\frac{1}{2}+\frac{2(2\alpha-s)}{3s(8\alpha-5s)}\delta_S+\frac{4}{3s(8\alpha-5s)}\delta_E^*\right)\\ &\cdot\left(\frac{h+\delta_H+w_2^E-w_1^E}{2h}\right),\end{aligned} \tag{B23}$$

and demand elasticty is given by

$$\begin{aligned}\eta_1^E=&-\frac{1}{2h}\frac{w_1^E}{(h+\delta_H+w_2^E-w_1^E)/(2h)}-\frac{4}{3s(8\alpha-5s)}\\ &\cdot\left(\frac{h+\delta_H+w_2^E-w_1^E}{2h}\right)\frac{w_1^E}{\hat{x}^{E^*}}.\end{aligned} \tag{B24}$$

It follows that for a given set of wholesale prices, $|\eta_1^E|>|\eta_1^{NE}|$. □

Lemma 6. *In distribution regime $C\in\{E, NE\}$,*

$$\frac{d\Pi_{H_1}^{C^{**}}}{d\delta_H}=(D_{A1}^{C^{**}}+D_{B1}^{C^{**}})\left(1+\frac{\partial w_2^{C^{**}}}{\partial\delta_H}\right).$$

Proof. From the envelope theorem and through implicit differentiation, we have that

$$\frac{d\Pi_{H_1}^{C^{**}}}{d\delta_H}=\frac{\partial\Pi_{H_1}^{C^*}}{\partial\delta_H}+\frac{\partial\Pi_{H_1}^{C^*}}{\partial w_2^C}\frac{\partial w_2^{C^{**}}}{\partial\delta_H}. \tag{B25}$$

Now, $\Pi_{H_1}^{C^*}=w_1^C(D_{A1}^{C^*}+D_{B1}^{C^*})$. We note that, under either distribution regime, $D_{A1}^{C^*}+D_{B1}^{C^*}$ depends only on $w_2^C-w_1^C+\delta_H$ (see (B8) and (B11)). Therefore, we have[33]

$$\frac{\partial\Pi_{H_1}^{C^*}}{\partial\delta_H}=\frac{\partial\Pi_{H_1}^{C^*}}{\partial w_2^C}=-w_1^C\frac{\partial(D_{A1}^{C^*}+D_{B1}^{C^*})}{\partial w_1^C}. \tag{B26}$$

Finally, we note that from the first-order condition for H_1's profit maximization, we have that

$$D_{A1}^{C^{**}}+D_{B1}^{C^{**}}+w_1^{C^{**}}\frac{\partial(D_{A1}^{C^*}+D_{B1}^{C^*})}{\partial w_1^C}=0. \tag{B27}$$

Substituting from (B26) and (B27) in (B25), we obtain the desired result. □

[33] We note that $\partial(D_{A1}^{C^*}+D_{B1}^{C^*})/\partial\delta_H=\partial(D_{A1}^{C^*}+D_{B1}^{C^*})/\partial w_2^C=-\partial(D_{A1}^{C^*}+D_{B1}^{C^*})/\partial w_1^C$.

Lemma 7. *When H_1 is exclusive to S_A and H_2 is exclusive to S_B, given the handset wholesale prices, the equilibrium service provider prices are given by*

$$F_{A1}^{EE*} = w_1^{EE} + \frac{1}{16}\left[(4\alpha-3s)\left(3-\frac{2}{8\alpha-5s}\delta_S\right)+\frac{8}{8\alpha-5s}\delta_{EE}^*\right]\cdot\left[s+\frac{4(2\alpha-s)}{3(8\alpha-5s)}\delta_S+\frac{8}{3(8\alpha-5s)}\delta_{EE}^*\right],$$

$$F_{B2}^{EE*} = w_2^{EE} + \frac{1}{16}\left[(4\alpha-3s)\left(3+\frac{2}{8\alpha-5s}\delta_S\right)-\frac{8}{8\alpha-5s}\delta_{EE}^*\right]\cdot\left[s-\frac{4(2\alpha-s)}{3(8\alpha-5s)}\delta_S-\frac{8}{3(8\alpha-5s)}\delta_{EE}^*\right],$$

$$p_A^{EE*} = \frac{1}{4}\left(s+\frac{4(2\alpha-s)}{3(8\alpha-5s)}\delta_S+\frac{8}{3(8\alpha-5s)}\delta_{EE}^*\right),$$

$$p_B^{EE*} = \frac{1}{4}\left(s-\frac{4(2\alpha-s)}{3(8\alpha-5s)}\delta_S-\frac{8}{3(8\alpha-5s)}\delta_{EE}^*\right),$$

where $j\in\{1,2\}$ and $\delta_{EE}^* = w_2^{EE} - w_1^{EE} + \delta_H$. Their equilibrium profits are given by

$$\Pi_{S_A}^{EE*} = \frac{1}{32s}\left(16\alpha-11s+\frac{4(2\alpha-s)}{3(8\alpha-5s)}\delta_S+\frac{8}{3(8\alpha-5s)}\delta_{EE}^*\right)\cdot\left(s+\frac{4(2\alpha-s)}{3(8\alpha-5s)}\delta_S+\frac{8}{3(8\alpha-5s)}\delta_{EE}^*\right)^2,$$

$$\Pi_{S_B}^{EE*} = \frac{1}{32s}\left(16\alpha-11s-\frac{4(2\alpha-s)}{3(8\alpha-5s)}\delta_S-\frac{8}{3(8\alpha-5s)}\delta_{EE}^*\right)\cdot\left(s-\frac{4(2\alpha-s)}{3(8\alpha-5s)}\delta_S-\frac{8}{3(8\alpha-5s)}\delta_{EE}^*\right)^2.$$

S_A's equilibrium subscription market share is given by

$$\hat{x}^{EE*} = \frac{1}{2}+\frac{2(2\alpha-s)}{3s(8\alpha-5s)}\delta_S+\frac{4}{3s(8\alpha-5s)}\delta_{EE}^*.$$

Proof. When H_1 is sold at S_A and H_2 at S_B, the indifferent consumer is located at

$$\hat{x}^{EE} = \frac{s+\delta_S+p_B^E-p_A^E}{2s}+\frac{\delta_H-F_{A2}^E+F_{B2}^E}{s(2\alpha-s-p_A^E-p_B^E)}. \tag{B28}$$

We then proceed as in Lemma 1 to obtain the desired results.

Appendix C. Proofs for Propositions in §§3 and 4

About Verifying Results Numerically in Propositions 1–5 We first note that given α, all other parameters in the model are bounded. Furthermore, by scaling s and δ_S with respect to α, and h and δ_H with respect to α^2, the model can be normalized with respect to α. Thus, the entire parameter space can be spanned numerically. And if our results hold for, say, $\alpha=1$, then they can be extended to any α.

Now the wholesale price strategies under the exclusive regime that are needed to verify Propositions 1–5 are only implicitly defined in Lemma 4 in terms of the variable d, which is the root of a certain cubic equation. As a result, we find that it is not possible to analytically verify the results and, therefore, must resort to a numerical approach. We follow a part analytical–part numerical approach where we substitute specific values for some of the parameters and then evaluate the resulting expressions analytically using Mathematica. For example, in the proof of Proposition (1), to show that $\Pi_{H_1}^{E**} - \Pi_{H_1}^{NE**} > 0$ when $\delta_H = -h(6h-1)/2$, where $\Pi_{H_1}^{E**}$ is known in terms of d, we set $\alpha=1$ and consider 100 specific equally spaced values of s in the range $[\frac{1}{3},1]$. For each specific value of s, we use Mathematica to show that whenever the condition for d in Lemma 4 is satisfied, $\Pi_{H_1}^{E**} - \Pi_{H_1}^{NE**} > 0$.[34]

In cases where we need to compute a derivative for an expression involving d, we use implicit differentiation. For example, in the proof of Proposition 1, to show $d(\Pi_{H_1}^{E**} - \Pi_{H_1}^{NE**})/d\delta_H < 0$ whenever $\Pi_{H_1}^{E**} - \Pi_{H_1}^{NE**} = 0$, we use implicit differentiation to obtain

$$\frac{d(\Pi_{H_1}^{E**} - \Pi_{H_1}^{NE**})}{d\delta_H} = \frac{\partial(\Pi_{H_1}^{E**} - \Pi_{H_1}^{NE**})}{\partial\delta_H} + \frac{\partial(\Pi_{H_1}^{E**} - \Pi_{H_1}^{NE**})}{\partial d}\frac{\partial d}{\partial\delta_H}, \tag{C1}$$

and $\partial d/\partial\delta_H$ is obtained by applying the implicit function theorem to Lemma 4. We then show the result numerically by setting $\alpha=1$ and considering a grid of specific values for s and h. For each point on this grid, we use Mathematica to show the desired result.

Proof of Proposition 1. An EHA occurs if $\Pi_{H_1}^{E**} - \Pi_{H_1}^{NE**} \geq 0$. It can be numerically shown that $\Pi_{H_1}^{E**} - \Pi_{H_1}^{NE**} > 0$ at the lower bound for δ_H in (4), and $\Pi_{H_1}^{E**} - \Pi_{H_1}^{NE**} < 0$ at the upper bound of δ_H in (4). Therefore, by continuity, there is at least one δ_{1H} such that $\Pi_{H_1}^{E**} - \Pi_{H_1}^{NE**} = 0$ when $\delta_H = \delta_{1H}$. Furthermore, it can be verified numerically that $d(\Pi_{H_1}^{E**} - \Pi_{H_1}^{NE**})/d\delta_H < 0$ whenever $\Pi_{H_1}^{E**} - \Pi_{H_1}^{NE**} = 0$. Hence, there must be only one such δ_{1H}.

Let z be one of the other parameters, $z\in\{\alpha,s,h,\delta_S\}$. Now when $\Pi_{H_1}^{E**} - \Pi_{H_1}^{NE**} = 0$, if $d(\Pi_{H_1}^{E**} - \Pi_{H_1}^{NE**})/dz > 0$, then because $d(\Pi_{H_1}^{E**} - \Pi_{H_1}^{NE**})/d\delta_H < 0$, δ_{1H} is increasing in z; if a small change in z increases the additional profits from an EHA, then δ_H must be higher to make H_1 indifferent again. The reverse is true if $d(\Pi_{H_1}^{E**} - \Pi_{H_1}^{NE**})/dz < 0$ when $\Pi_{H_1}^{E**} - \Pi_{H_1}^{NE**} = 0$. We numerically verify the sign of $d(\Pi_{H_1}^{E**} - \Pi_{H_1}^{NE**})/dz$ when $\Pi_{H_1}^{E**} - \Pi_{H_1}^{NE**} = 0$ to verify the remainder of the proposition.

Proof of Proposition 2. We verify numerically that there is a cost-raising effect, that it is larger than the variety effect, and that H_1's wholesale price is higher. We note that H_1's market share must be lower than under the nonexclusive regime when $\delta_H = \delta_{1H}$ because its wholesale price is higher but the profits are the same as in the nonexclusive regime. We verify numerically that H_1's market share when it is exclusive is decreasing in δ_H. Finally, we verify numerically that at the lower bound for δ_H in (4), H_1's market share is higher than in the nonexclusive regime only if s is sufficiently small, h is sufficiently large, or δ_S is sufficiently large.

Proof of Proposition 3. Since $\hat{y}_A^{E**} > 0$, it follows that the rival service provider is always worse off. We verify numerically that the rival handset vendor is always better off.

[34] See footnote 31 about Mathematica.

Proof of Proposition 4. Since $\hat{y}_A^{E**} > 0$, it follows that the service usage fee for the exclusive handset service provider (excluded service provider) is higher (lower) than without the exclusive tie-in. It further follows that the average service usage is lower because consumers are not buying service from the their most preferred service provider. The rest of the results are verfied numerically.

Proof of Proposition 5. We verify this proposition numerically.

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