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Tipping in Two-Sided Markets with Asymmetric Platforms*

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Abstract

This paper examines tipping in the Armstrong (2006) two-sided market model. By adding simple cost asymmetries to the original model, we show that the model is quite robust to differences in network size and deviations from 50-50 market share. It well represents situations where asymmetries compensate for one another; for example, one platform might incur marginal costs to court developers and make up for it with lower costs to users. Our tests also make clear that there is an implicit stand-alone utility in the Armstrong model even when it is not specifically modeled. These results improve interpretation of the many studies that use the Armstrong model for policy analysis.

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1 Introduction

Two-sided markets, such as social networks, operating systems, and payment cards are increasingly important in business and in antitrust and regulatory policy The platforms that facilitate these markets must attract sufficient participation from two different groups (sides) in order to remain in the market. When participation is too low on one platform, the market is said to *tip,* and all agents from both sides join the platforms that remain in the market.For example, in 2008 the market for high-definition blue laser video discs tipped, with Toshiba's HD DVD format losing to Sony's Blu-Ray format.[1]

The importance of two-sided markets has given rise to a large economics literature, including many theory papers focusing on various strategic and policy questions. A large percentage of these papers build on the model of Armstrong (2006), which considers "pure participation externalities." That is, both buyers and sellers pay lump-sum access prices to join the platform, and they exert positive indirect network effects on one another that are not affected by the volume of trade but only by their participation. In general, the result is that lower prices are provided to the side of the market that is more competitive or provides more benefit to the other side. on of which side to give the product to relies on the magnitude of the inter-side network effects.[2] Armstrong's paper employs a "no-tipping assumption" that simply rules out parameter values that would cause the

[1] The straw the broke the camel's back was the January 4, 2008 announcement by Warner Bros. Entertainment that they would be producing exclusively in the Blu-Ray format. See Carnoy, D., "Warner goes Blu-ray exclusively, delivering crushing blow to HD DVD," CNET News (2008). Sony has been involved in repeated media format wars, including the well-known VHS versus Betamax competition of the 1980s.

[2] Armstrong and Wright (2007) allow for variation in product differentiation across the two sides of the market (i.e. sellers are *ex-ante* indifferent between the two platforms, while buyers may have a preference for one side over the other), and they endogenize the choice to multihome. They find that platforms do not compete directly for sellers, but instead compete indirectly by attracting more buyers. Additionally, they find that sellers endogenously choose to multihome if product differentiation between the two platforms is sufficiently small.

market to tip. In this paper, we ask what are the effects of this assumption when the model is applied to real-world policy situations.

Applications of the Armstrong model are common. Hagiu (2009) extends it by adding a dimension of intra-platform competition and investigates discrepancies in pricing between video game and computer software markets. Choi (2009) uses the model to investigate the practice of tying and its relation to multi-homing. Economides and Tåg (2011) use it to examine network neutrality. Indeed, the first FCC order on network neutrality, *Preserving the Open Internet rule,* 47 CFR Parts 0 and 8, cites Armstrong (2006). Lin (2011) examines television programming, Hildebrand (2012) derives an empirical test for network effects, and Rasch and Wenzel (2013, 2014) examine the role of software piracy and compatibility between the platforms, all using the Armstrong model.

All of the above models preserve Armstrong's no-tipping assumption, so that by assumption platforms are sufficiently symmetric. In this paper, we ask what would happen if the platforms were not symmetric. How large can these asymmetries become before the no-tipping assumption is violated? In particular, are the assumptions of the models within reasonable bounds relative to real-world platforms? Our answer will be a qualified yes, with the one caveat that the stand-alone value of a platform (i.e. its value apart from its complementary components or users) must be sufficiently large for the Armstrong model to be a sensible representation of reality.

The paper is organized as follows. The next section discusses the literature on the tipping phenomenon in two-sided markets. Section 3 presents an extension of Armstrong's model in which cost asymmetries make the equilibrium market shares of two platforms different. Section 4 discusses what causes the market to tip and establishes how large the asymmetries between platforms can become without tipping the market. Section 5 concludes.

2 Literature on Tipping

Rysman (2009) gives three general conditions that promote tipping. First, there may not be much horizontal product differentiation between platforms. Second, agents on at least one side may use only one platform rather than simultaneously using more than one (Sun and Tse (2007) show that such "single-homing" is associated with tipping). Third, if the seller side of the market produces highly differentiated products, sellers may strategically favor tipping since the resulting single-platform competition will be relatively soft.

Evans and Schmalensee (2010) note that tipping is a feature of networks with once-for-all demand decisions, as in Armstrong and the present paper. If consumers can change their demand decisions, then a dynamic model is needed, and Evans and Schmalensee say, "We suspect that the importance of tipping, which results when one network attains a marginal lead that becomes an unstoppable competitive advantage, has been overstated, in part because of the literature's general assumption that switching costs make participation decisions irreversible."

Bolt and Tieman (2008) study what happens tipping in a monopoly platform model with constant elasticity demands. They show that prices are lowered to a minimum on the market side with more elastic demand, and raised to a profit-maximizing level on the lower-elasticity side. Ambrus and Argenziano (2009) model pricing and network choices in a two-sided market that allows for heterogeneity of consumer valuation of the network externality. They demonstrate that under monopoly or competition, multiple asymmetric networks can exist in equilibrium if there is sufficient consumer heterogeneity. They show that for all asymmetric equilibria, one platform is cheaper and larger on one side and the other is the opposite. Bakos and Katsamakas (2008) show that asymmetric prices as a result of each side's valuation of the other can be the efficient cost structure in two-sided markets even without the existence of asymmetric costs.

Empirical work confirms increased concentration and tipping in markets for home video game systems asa aresult of network effects. Dube et al.

(2010) use counter-factual simulations of videogame markets where there are no indirect network effects and find that in real markets (with network effects) the individual firm concentration ratio is 23% higher. They argue that, "Two standards ... could be identical *ex-ante* but ... due to the emergence of positive feedback and the role of expectations, markets with indirect network effects may become concentrated, i.e. tip towards one of the competing standards," (pg. 3). Additionally, Corts and Lederman (2009) study different generations of consoles in the U.S. home video game market and provide evidence for early dominance of the market by one firm (Nintendo), with higher degrees of market sharing becoming evident in later generations. They argue that the increasing prevalence of non-exclusive software constitutes a form of compatibility and allows for indirect network effects between owners of competing and incompatible hardware, decreasing market concentration relative to exclusive network effects.

3 Model

As in Section 4 of Armstrong (2006), consider two two-sided platforms engaged in differentiated Bertrand competition. Platforms set access fees to both sides of the market, and then buyers and sellers simultaneously decide which platform to join. The platforms are modeled as completely incompatible – components designed for one platform do not function on the other, and buyers and sellers single-home on just one platform.

There are two sides: sellers (developers) denoted by S and buyers (end-users) denoted by B. The number of agents on side $k = B, S$ of platform $i = 1, 2$ is n_{ki}. We normalize and assume market coverage so that $n_{k1}+n_{k2} = 1$. Platform i's access price to side k is p_{ki}.

Consumer utility and developer profit on platforms $i = 1, 2$ are

$$U_i = \alpha n_{Si} - p_{Bi} - t_B\theta_B \qquad \pi_i = \beta n_{Bi} - p_{Si} - t_S\theta_S. \tag{1}$$

The parameters in (1) are as follows:

- α and β – strengths of network effects on buyer and seller sides
- θ_B and θ_S – individual agents' locations on the unit interval (uniformly distributed)
- t_B and t_S – Hotelling transport costs for buyers and sellers

Although one can solve the model with this full set of parameters, this produces complex formulas for the equilibrium prices and market shares that are not easily interpreted. We believe that the points of this paper can be made more clearly by making the product differentiation and network effects the same on both sides of the platforms: $t_B = t_S = 1$ and $\alpha = \beta$. This simplification does not change the flavor of the results; in the more complex version, prices and market shares have partial derivatives of the same sign with respect to each of the parameters.

We solve for the indifferent consumer and indifferent developer à la Hotelling. The number of users on each side is given by

$$n_{B1} = \frac{1}{2} + \frac{t(p_{B2} - p_{B1}) + \alpha(p_{S2} - p_{S1})}{2(t^2 - \alpha^2)} \qquad n_{S1} = \frac{1}{2} + \frac{t(p_{S2} - p_{S1}) + \alpha(p_{B2} - p_{B1})}{2(t^2 - \alpha^2)}$$

We place no restrictions on p_{ki} because in many two-sided markets one side is charged a zero price or is even subsidized. In some cases, such a subsidy can come in the form of development kits and other non-monetary incentives.

Next we introduce an asymmetry between the platforms. Let each platform i incur marginal costs f_{ki} to serve each side of the market, and let platform 1's cost advantage (or disadvantage) be denoted $\delta_k = f_{k2} - f_{k1}$.[3]

Platform i's profit function is then

$$\Pi_i = (p_{Si} - f_{Si})n_{Si} + (p_{Bi} - f_{Bi})n_{Bi} \tag{2}$$

[3]While the cost differences are written as marginal costs, they are linear and thus interchangeable with linear quality differences between the platforms. (We thank Patrick Rey for pointing this out.) For example, software platforms often compete for sellers based on choice of programming language, hardware requirements, existence of knowledge spillovers, and the quality of application programming interfaces (APIs) rather than price.

3.1 Equilibrium

The platforms play a differentiated Bertrand game, each simultaneously choosing its price to the buyer and seller sides of the market. Each platform will maximize (2), so it is necessary to satisfy the second order conditions for a profit maximum. For platform 1, the second order conditions are:

$$\frac{\partial^2 \Pi_1}{\partial p_{S1}^2} < 0 \quad \frac{\partial^2 \Pi_1}{\partial p_{B1}^2} < 0 \quad \frac{\partial^2 \Pi_1}{\partial p_{S1} \partial p_{B1}} > 0 \tag{3}$$

For the simplified model we have presented above, all three second order conditions reduce to just a single inequality:

$$t > \alpha \tag{4}$$

The first order conditions – one for each price on each platform – constitute a system of four linear equations in four unknowns. We can therefore solve for the equilibrium prices as functions of parameters alone. For buyers these are

$$p_{B1}^* = (t - \alpha) + \frac{2f_{B1} + f_{B2}}{3} \qquad p_{B2}^* = (t - \alpha) + \frac{2f_{B2} + f_{B1}}{3} \tag{5}$$

Note that the inter-platform price difference is

$$p_{B2} - p_{B1} = \frac{\delta_B}{3} \tag{6}$$

For sellers, the prices are

$$p_{S1}^* = (t - \alpha) + \frac{2f_{S1} + f_{S2}}{3} \qquad p_{S2}^* = (t - \alpha) + \frac{2f_{S2} + f_{S1}}{3} \tag{7}$$

The price formulas consist of two parts: the weighted average of the marginal costs of both platforms and a markup term $t - \alpha$ that reflects product differentiation and network effects. Since a platform's price is based on a weighted average of marginal costs, it is possible in some cases for the duopoly equilibrium to include price below marginal cost to one side of the market. This is not for the familiar two-sided reasoning that network effects are stronger on one side than the other – here we have assumed α is the same on both sides. Rather, this is a differentiated Bertrand oligopoly outcome that allows a high-cost platform to charge below marginal cost on one side and make it up on the other.

In equilibrium, the number of buyers and sellers on platform 1 is

$$n^*_{B1} = \frac{1}{2} + \frac{t\delta_B + \alpha\delta_S}{6(t^2 - \alpha^2)} \qquad n^*_{S1} = \frac{1}{2} + \frac{t\delta_S + \alpha\delta_B}{6(t^2 - \alpha^2)} \tag{8}$$

4 Tipping

4.1 No-Tipping Condition

The equilibrium we have found is a version of Armstrong (2006) with asymmetric costs. In Armstrong's original model, $\delta_B = \delta_S = 0$. When Armstrong presents the Bertrand-Nash equilibrium, he writes that if the second order conditions hold, "Then the model with two-sided single-homing has a unique equilibrium that is symmetric." (pg. 675)

In our asymmetric version, the second order conditions still guarantee uniqueness, but symmetry no longer occurs. This introduces a new issue not present in Armstrong's paper: the mathematical solution to the Bertrand-Nash equilibrium could occur at values such that one platform has a negative number of users on one side of the market. Since this is not economically meaningful, we need additional conditions beyond just the second-order conditions.

These additional conditions come in the form of constraints on the cost asymmetries relative to the product differentiation and network effects parameters. These are easiest to present if we restrict attention to each type of cost asymmetry in turn. First consider the case where the costs are the same on the seller side but differ on the buyer side.

Proposition 1: Let seller side costs be equal, so $\delta_S = 0$. Then the buyer market remains untipped ($n_{Bi} \in (0, 1)$ $i = 1, 2$) if and only if

$$|\delta_B| < \frac{3}{t}\left(t^2 - \alpha^2\right) \tag{9}$$

and the seller market remains untipped ($n_{Si} \in (0,1)$ $i = 1, 2$) if and only if

$$|\delta_B| < \frac{3}{t}\left(t^2 - \alpha^2\right)$$

Proof: Follows directly from (8).

Several insights come from this result. First, an untipped equilibrium can be supported under greater cost asymmetries when either horizontal product differentiation t is larger or network effects α are smaller. Second, existence requires $t > \alpha$, so an asymmetry in cost of serving buyers implies a more stringent constraint on the buyer side than on the seller side; thus, (9) is the only salient constraint. This implies that the market could continue to remain untipped on one side even if there were no users on one side of one platform. The reason this is possible is that both Hotelling markets are always assumed covered – there is no outside option. Thus, if the price is low enough, some users will be willing to join a platform with no users on the other side. This indicates the implicit presence of a stand-alone utility or intrinsic value in the Armstrong model.

Similar results obtain if we let $\delta_B = 0$ and examine the effect of δ_S on the market. We should point out that all of the bounds on the δ's are strictly greater than zero for parameter values that satisfy the second order condition. Therefore, the model does support interior equilibria where one platform is bigger than another, and can even support interior equilibria where one platform is simultaneously bigger on one side and smaller on the other.

An increase in the cost advantage of platform 1 on one side of the market will increase platform 1's market share on both sides. The relevant derivatives[4] are

$$\frac{\partial n_{B1}}{\partial \delta_B} = \frac{t}{6(t^2 - \alpha^2)} \qquad \frac{\partial n_{S1}}{\partial \delta_B} = \frac{\alpha}{6(t^2 - \alpha^2)} \tag{10}$$

Since the second order condition requires $t > \alpha$, both these derivatives are positive. Also, a cost advantage on one side positively affects the number

[4] We focus on buyer-side asymmetries only; analogous results hold for the seller side.

of users on both sides, but the own-side effect is stronger:

$$\frac{\partial n_{B1}}{\partial \delta_B} > \frac{\partial n_{S1}}{\partial \delta_B} > 0$$

4.2 Interpretation of the Tipping Constraint

One important question when using this model to address real-world concerns is whether the tipping constraint is economically important or merely a mathematical curiosity. Recall the second order condition is $t > \alpha$. From the buyer utility function, we know that α is the value of going from $n_S = 0$ to $n_S = 1$, that is, it represents a buyer's consumer surplus generated by the entire universe of sellers.

The meaning of t, on the other hand, is the money-equivalent utility loss from forcing the least enthusiastic potential buyer of platform 1 (the buyer at $\theta_B = 1$) to use that platform nonetheless. The same goes for the least enthusiastic buyer of platform 2 switching to platform 1.

Taking these together, we have the following interpretation:

Proposition 2: The second order condition, $t > \alpha$, requires that an agent of *any* θ type must value *all* the components from the other side of the market less than the monetary compensation needed to persuade the most extreme θ types ($\theta = 0$ and $\theta = 1$) to switch from one platform to another. This condition is still required even when there is a common intrinsic value v added to all users' gross utility of joining each platform.

To put Proposition 2 in anecdote form, consider the most fanatical Apple Macintosh user. The second order condition requires that this most fanatical user would not convert to PC even if *all* the software in the market was for PC and *none* for Mac. Likewise the most fanatical Xbox gamer would not convert to Playstation even if every single game developer switched to Playstation.

We thus conclude that the Armstrong model is an accurate description of reality only when there is a sufficiently large differential in type-specific gross utility. Since this difference must be greater than the total value of software for some users, there must be significant intrinsic features of the platforms that are not related to network effects and that are also not related to any common intrinsic value. Examples would include specific learning to operate a platform, design features, or stand-alone uses that are not present on both platforms.[5]

Now consider the salient tipping constraint (9) in the asymmetric model. If we rewrite (9) in terms of α and t we get

$$\alpha^2 < t^2 - \frac{1}{3} t\delta_B$$

If there is no difference in the costs and equilibrium market shares of the two platforms, then $\delta_B = 0$ and this restriction reduces to the second order condition. But if there is initially a cost advantage, and thus a larger than 50% market share for platform 1, the bound on the network effect is smaller. To add this to our anecdote, if there is an asymmetry, then the no-tipping condition requires that not just the single most fanatical user, but a whole block of fanatical users near the endpoints of the Hotelling line would not switch to, say, Macintosh even if all software were available only for the PC.

4.3 Compensating Cost Advantages

We now allow for compensation between cost advantages δ_S and δ_B such that each side maintains a constant membership level. We derive expressions for partial effects of each δ on the other, given a fixed level of n_{ki}.

Suppose there is a \$1 increase in platform 1 buyer side cost, so δ_B falls by 1. The number of buyers on platform 1 would remain unchanged if platform 1's seller side cost decreased by

$$\left.\frac{d\delta_S}{d\delta_B}\right|_{n_{B1}} = -\frac{t}{\alpha}$$

[5] Note that this excludes the often-discussed ability of both VHS and Betamax to record live TV, since this capability was present on both systems.

and the number of sellers on platform 1 would remain unchanged if platform 1's seller side cost decreased by

$$\left.\frac{d\delta_S}{d\delta_B}\right|_{n_{S1}} = -\frac{\alpha}{t}$$

Any increase in either δ_B or δ_S is always advantageous to platform 1, so it is obviously in the platform's interest to implement cost reductions whether they "compensate" for other changes or not. But the compensation results may be highly relevant when government policy changes or vendor innovations cause exogenous changes in the costs of serving the two sides.

4.4 Towards and Empirical Interpretation

The no-tipping constraints are rather abstract, so let us relate them to the markup over marginal cost to make them more concrete. First, suppose that platform 2's buyer-side costs are a multiple m of platform 1's, so that $f_{B2} = (1+m)f_{B1}$. In that case, $\delta_B = mf_{B1}$. Next, let us think of price in terms of markup over marginal cost, so that, for example, platform 1's buyer price could be written $p_{B1} = (1+\mu)f_{B1}$. Since the markup term in the price equations is $t-\alpha$, any observed markup μ would then correspond to $t-\alpha = \mu f_{B1}$ when the marginal costs were equal. Then we can rewrite the first inequality in Proposition 1 as

$$mf_{B1} < 3\frac{t^2-\alpha^2}{t}$$

$$\frac{m}{\mu}(t-\alpha) = 3\frac{t^2-\alpha^2}{t}$$

$$m < 3\left(1+\frac{\alpha}{t}\right)\mu$$

The last version of the inequality says that platform 2 can have a cost multiple at least 3 times the price-cost markup of platform 1 and the market will remain untipped. Thus, despite the linearity of the Armstrong model, it is quite forgiving in terms of what cost asymmetries can be sustained as an interior solution.

5 Conclusion

We solve both sides of an asymmetric two-sided market model to find how various parameter changes can affect the market equilibrium. We find that some level of inter-platform asymmetry in costs is tolerable before the market tips fully on either side, and cost asymmetries can compensate for each other to maintain a given membership share on each platform.

We have also shown that when interpreting the Armstrong model, there must be a stand-alone value of the platform to both buyers and sellers. Otherwise the second-order conditions do not make economic sense because they impose limits on the value that can come from indirect network effects across the two sides of the market.

Overall our conclusion is that the Armstrong model is fairly robust to asymmetries. In particular, our example using price-cost margins suggests that platforms can be quite different without violating the no-tipping constraints.

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