

Effects of Mergers on Incentives for New Technology Adoption

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Abstract

We analyze how market structure, technology costs, and network effects interact to impact adoption of advanced technologies. This issue has arisen recently in at least two recently failed mergers: The AT&T proposal to acquire T-Mobile's U.S. assets and the proposed GE-Honeywell merger. The former raised the issue of whether increased industry concentration could speed the adoption of advanced wireless communications. The latter raised the issue of rivals are impacted by technology adoption. We find plausible conditions under which increased industry concentration can make technology adoption more profitable for both merging companies and for rivals.

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I. Introduction

We examine how mergers affect incentives for adopting new technologies that increase quality for customers. This issue has arisen in at least two cases where government opposition to proposed mergers apparently led companies to cancel their merger plans. In the proposed merger of GE and Honeywell in 2001, the European Union Competition Commission (EUCC) denied the merger¹ even though the competition regulators in the U.S. and Canada had already approved it. One of the EUCC's concerns was that the combination of GE's aviation engines and financial capabilities, with certain other products produced by Honeywell would allow the merged company to develop product offerings that rivals could not match. For example, the Commission concluded that the combination of GE Capital and the merged company's aircraft engine business would allow it "to take more risk in product development programmes than any of its competitors." (§ 108) The EUCC believed that this would harm competition.

More recently the U.S. Department of Justice (DOJ) acted to stop AT&T's acquisition of T-Mobile's U.S. assets based on the concern that the merger would result in the loss of an aggressive price competitor, namely T-Mobile. The merging parties had argued that the merger would enhance their abilities to adopt an advanced wireless technology. More specifically AT&T argued that acquiring T-Mobile's radio spectrum would make it more economical to deploy fourth generation (4G) wireless communications services in the U.S.

We examine these issues by simulating the effect that increased industry concentration has on firms' propensities to adopt new technologies that provide customers with higher valued services. We focus on firms' incentives to deploy known technologies rather than to discover

¹ *General Electric/Honeywell*, Commission Decision, Case COMP/M. 2230, July 3, 2001.

new ones as the former was an issue in both of the merger cases cited above.² Our findings challenge the conclusions of the competition authorities in the U.S. and Europe. We find that under certain conditions a decrease in the number of competitors in a market may indeed increase the propensity of a merged firm to adopt a new technology, and customers can benefit even if the merger results in the loss of an aggressive price competitor. These results hold for both Cournot and Bertrand competition in differentiated products.

The U.S. competition regulator was somewhat vague in what it meant for T-Mobile to be an aggressive price competitor. On one hand, below-normal production costs could lead a firm to appear to be more aggressive in its pricing than its rivals, but low production costs are inconsistent with T-Mobile's small market share. We examine two alternative interpretations of the government's observations on pricing. One possible explanation is that T-Mobile chooses price as its strategic variable while the other firms compete *à la Cournot*. We examine this, but it too is an unsatisfactory explanation because we find that such a mixture of choices of strategic variables results in the smaller rival having higher prices rather than lower prices than its Cournot competitors. Another interpretation, which seems more likely, is that customers find the smaller firm's services to be of lower value. This could result from T-Mobile having less coverage than either AT&T or Verizon and would lead to both lower prices and lower market share.

We address the EUCC's concern about effects of quality on rivals by examining how a new technology adoption by one firm affects the propensity of other firms to also adopt the technology. We find that the merger increases the incentives of the non-merging firms to improve their product quality, which can benefit customers. This implies that, had the GE-

² We define the GE-Honeywell case as adoption of a known technology because the EUCC was concerned about the merged company's portfolio of products rather than the development of new technologies.

Honeywell merger been allowed, rivals might have had a greater incentive to provide more valuable products after the merger than it appeared they had prior to the merger.

We demonstrate these results by examining a network industry á la Katz and Shapiro (1985) in which operators choose their technologies and network sizes after customers have formed expectations, but also examine scenarios in which the firms might compete on price and scenarios in which network effects do not exist. We define equilibrium as the situation in which customers' expectations are met and each operator has no incentive to change its decisions given the choices of customers and other operators. Operators incur larger fixed costs if they adopt the more advanced technology than if they choose the standard technology. We identify threshold levels of fixed costs for the advanced technology. If fixed costs for the advanced technology are less than (alternatively, greater than) the threshold, then a profit maximizing operator would (alternatively, would not) optimally adopt the advanced technology. We find that a merger between two operators decreases the threshold level of fixed costs for the merged firm and for its rivals, which implies that the merger increases the likelihood of adoption of the advanced technology. We are unable to demonstrate some of our results analytically, so we conduct simulations to derive our conclusions.

The remainder of this paper is organized as follows. Section II describes the industries that were subject the adverse merger decisions by the competition authorities. Section III describes our analytical model. Section IV analyzes incentives to adopt the advanced technology. Section V is the conclusion. The Appendix describes the simulations.

II. Industry Contexts

Wireless Communications Industry

One industry issue that prompts our research was a proposed merger in cellular telecommunications in the United States. Although cellular telephony was technically feasible in the late 1960s and early 1970s, the service was not made commercially available the United States until the 1980s. This delay occurred in part because potential service providers needed permission from the U.S. Federal Communications Commission (FCC) to use a portion of the radio spectrum for the service, and the FCC moved slowly in issuing cellular licenses. Different types of radio communications use specific parts of the radio spectrum, denoted by frequency, and the FCC requires operators to have licenses to use the spectrum. (Crandall and Jackson, 2001)

Cellular telephony works by allowing customers' phones to communicate via signals carried in the electromagnetic radio spectrum. What differentiates cellular telephony from other forms of radio communications is that cellular technologies allow customers to move about more freely while continuing a communications session. (Padgett, Gunther, and Hattori, 1995) This is accomplished by dividing geographic areas into cells, each of which is served by a radio antenna, and using the cellular technology to hand off a customer from one cell to another as the customer moves, all without disrupting the customer's session as long as each cell involved in the session has sufficient capacity to serve all of the customers trying to engage in sessions simultaneously in that cell.

Technologies for cellular telephony have changed over time. The first generation (1G) technologies, launched in Japan in the late 1970s, used analog signals. Second generation (2G) technologies became commercially available in the 1990s. There were several 2G technologies,

but many governments around the world directed their telecommunications providers to use a technology called GSM. The United States was one of the few countries to allow operators to choose their technologies and so a number of technologies were deployed in the country, including GSM, CDMA, and TDMA. 2G technologies used digital signals and so could provide better service than 1G technologies, but 2G services were limited to traditional voice communications and small amounts of data. (Padgett, Gunther, and Hattori, 1995; Hommen and Manninen, 2003)

Broadband cellular service evolved out of the 2G technologies. Even though there were several incremental steps, taken in the form of 2.5G and 2.75G technologies, the first widely used cellular broadband was 3G, which stands for third generation. A primary difference between 2G and 3G was that 3G allowed for greater data transmission and for certain types of video transmission. 3G provides superior data services than 2G, but lacks sufficient functionality and bandwidth for many advanced services. (Roche, 2003; Suk and Yeung, 2003; Frattasi et al., 2006; FCC, 2011)

4G technologies are intended to address this shortcoming of 3G (Govil, 2008). There are competing 4G technologies, including HSPA+ used by AT&T and T-Mobile at the time of their proposed merger, WiMAX used by Clearwire / Sprint Nextel, and LTE being deployed by AT&T, Verizon, and MetroPCS (FCC, 2011). HSPA+ is a higher bandwidth form of HSPA (High Speed Packet Access), which is used in some 3G networks. An advantage of HSPA+ is that it can evolve from some 3G networks. LTE (Long Term Evolution) and WiMAX are often viewed as being more advanced and offering higher transfer speeds than HSPA+, but they cannot

evolve from existing 3G networks and so require additional radio spectrum.³ (McCormick, 2010; FCC, 2011)

An issue for operators trying to deploy 4G has been the availability of bandwidth in the radio spectrum. To deliver the services promised, LTE requires additional unencumbered radio spectrum. Radio spectrum is unencumbered in this context if it is not currently being used for other services or other technologies. This presents challenges for service providers because, in many instances, governments are slow in providing additional radio spectrum for 4G services. There are various reasons for the delays, but there is general consensus that additional radio spectrum for cellular service would speed deployment of 4G. Operators may be able to overcome this spectrum limitation in part through improved engineering of their systems and migration of customers off of older technologies, but this approach raises costs and does not eliminate the physical limitation of radio spectrum capacity. (FCC, 2011; McCormick, 2010)

According to the companies involved in the proposed merger, this spectrum limit was a motivating factor behind their desire to merge. Although both operators advertised 4G HSPA+ services, T-Mobile had no plans to upgrade to LTE at the time of the proposed merger (FCC, 2011). AT&T planned to upgrade to LTE, but held that spectrum limitations made the LTE rollout more costly and more limited than would otherwise be the case. According to the two companies, if AT&T had T-Mobile's radio spectrum, AT&T's rollout of 4G LTE would be faster, more widely spread and more economical. (AT&T et al., 2011)

However, a merger of two operators serving essentially the same markets raises antitrust issues, especially when markets appear concentrated. For example, AT&T and Verizon together account for over 60 percent of the cellular customers served nationwide. (FCC, 2011) A typical

³ There are disagreements on the performance differences between HSPA+, LTE, and WiMax. For examples of tests, see phone.Arena.com (2011) and Segan (2010).

horizontal merger analysis would probably indicate that a merger involving at least one of these two carriers would decrease competition and reduce net consumer surplus. What was different for the AT&T acquisition of T-Mobile's operations was the potential impact on technology evolution. If the acquisition made faster deployment of 4G LTE technologies more economical, both operators and customers could have benefitted from the merger despite the increased industry concentration.

Avionics

GE and Honeywell produced complementary product lines in the civil aerospace industry and sought a merger in part to exploit the potential synergies. GE produced and serviced large aircraft engines, and had a financial subsidiary, GE Capital. Honeywell made small aircraft engines and various avionics and non-avionics components. The EUCC concluded that the merged company would "be able to offer a package of products that has never been put together on the market prior to the merger and that cannot be challenged by any other competitor on its own." (§ 350) In particular, the combination of GE's engines, GE Capital's financing capabilities and Honeywell's products would result in lower prices in a way that would "induce customers to buy GE engines and Honeywell . . . products over those of competitors, thus increasing the combined share of GE and Honeywell on both markets." (§ 353) "Airlines generally welcome the financial incentives that come with bundled offers. Given the very nature of their competitive environment, airlines are under great pressure in the short-term to keep their costs under control." (§ 449)

III. The Model

We consider a situation where up to $N = 3$ profit maximizing firms compete in the market for a product with possible network effects. Let n represent the number of firms actually

competing in the market. Nature moves first and determines whether firms compete by choosing prices or output. In the next stage of the game, each firm i , $i = 1, 2, 3$, chooses its technology $t = \{L, H\}$ and can choose only one technology. Technology L could be 3G services or standard avionics products and H could be the provision of 4G LTE services or combined avionics and financing options. The requirement of a firm choosing only one technology biases our results against the advanced technology because upgrading necessitates the adopting firm giving up the profits it could receive from the less advanced technology. Next customers set expectations about the size of each firm's output, \hat{x}_i , and then firms' compete in prices or output.

Each firm incurs a fixed cost $f_i(t) \geq 0$ and constant marginal production costs $c_i(t) \geq 0$, both of which we normalize to zero when $t = L$. If a firm chooses H , then the firm incurs a fixed cost $f_i(H) \geq f_i(L)$ and constant marginal production costs $c_i(H) \geq c_i(L)$. We analyze threshold levels for fixed costs, above which it is unprofitable for an operator to adopt the advanced technology. A higher (conversely, lower) threshold increases (conversely, decreases) the propensity of adoption of the advanced technology.

Let p_i^t represent the price that firm i charges for its service after adopting technology t . We adapt Katz and Shapiro (1985) to accommodate each customer having a non-negative preference for his or her network provider. This gives an inverse demand for each firm $p_i^t = A + \alpha^t + v \sum_{j=1}^n \hat{x}_j - \sum_{k=1}^n \sum_{j=1}^n b_{j,k} x_j$, where $b_{j,k} \geq 0$ represents a customer of j 's product innate preferences regarding supplier k and $a^H \geq a^L = 0$ represents the improvement in quality if a firm chooses the advanced technology.

We can now specify firm i 's objective function as

$$\max_{x_i, t_i} \pi_i \equiv (p_i(t, x_1, x_2, x_3) - c_i(t))x_i - f_i(t)$$

subject to

$$\begin{aligned}
0 &\leq x_i \leq \bar{x}_i \quad \forall i \\
0 &\leq p_i \leq \bar{p}_i \quad \forall i \\
t &= \{L, H\}.
\end{aligned}$$

if the firm competes by choosing output and

$$\max_{x_i, t_i} \pi_i \equiv (p_i - c_i(t))x_i(t, p_1, p_2, p_3) - f_i(t)$$

subject to

$$\begin{aligned}
0 &\leq x_i \leq \bar{x}_i \quad \forall i \\
0 &\leq p_i \leq \bar{p}_i \quad \forall i \\
t &= \{L, H\}.
\end{aligned}$$

if the firm chooses price.

We assume an exogenous merger of two of the firms, 1 and 3, and denote the merged firm as m . To go into effect, the merger must be approved by a regulator, whose objective is to maximize weighted social welfare, where $\lambda = (\frac{1}{2}, 1]$ is the weight placed on net consumer surplus and $1 - \lambda$ is the weight placed on producer profits.

The sequencing of the game is as follows. First, nature determines whether each firm competes by choosing output or price. Then the regulator decides whether to approve the merger and then firms' choose their technologies. Then customers form expectations about each firm's output. Next firms choose outputs (alternatively prices) and prices (alternatively outputs) result. Finally, customers choose their suppliers and payments are provided as promised.

IV. Incentives to Adopt Advanced Technologies

In this section we analyze how an exogenous merger impacts incentives to adopt the advanced technology. We examine three competition scenarios: Cournot competition, Bertrand competition, and mixed competition, where at least one firm chooses price while its rival(s)

choose output. The following Lemma describes how the competition scenarios affect market outcomes.

Lemma 1. All other things being equal,

1. Cournot competition results in higher prices and profits and lower output than the other forms of competition.
2. The price chooser in mixed competition has lower prices, output and profits than if the firm competed á la Cournot with its rivals, but its prices are higher and its output and profits lower in mixed competition than those of its rivals.
3. Bertrand competition results in lower prices and profits and higher output than the other forms of competition.

The Bertrand and Cournot results in Lemma 1 are well known. We are unaware of analyses of mixed competition, so we examine why when an otherwise Cournot market has one firm choose price rather than output, the price chooser has higher prices than its rivals. The outcome results from the interaction of strategic complements and substitutes. With Cournot competition, the individual firm's outputs are strategic substitutes, meaning that if firm i were to increase its output, firm j 's best response would be to lower its output, and vice versa. With mixed competition, if firm i chooses price and j chooses output, firm i 's price is a strategic complement to firm j 's output, but firm j 's output is a strategic substitute for firm i 's price. As a result, firm i 's reaction function to j corresponds to Bertrand competition, which lies below firm i 's Cournot reaction function in price space, but firm j 's reaction function is the same as in Cournot competition. Figure 1 illustrates this result.

[INSERT FIGURE 1 ABOUT HERE]

In Figure 1, the Cournot reaction functions, i.e., each firm chooses output in response to its rival's strategic choice, are expressed as resulting prices. We label these as output reaction functions expressed as price. We label the Bertrand reaction functions as price reaction functions. These lie inside the Cournot reaction functions in price space, leading to lower prices and higher outputs. In mixed competition, firm i chooses price in response to firm j 's strategic choice and the reaction function corresponds to firm i 's reaction function with Bertrand competition. Firm j 's reaction function is the same as its Cournot reaction function. The result is lower prices than with Cournot competition, but firm i has a lower price than firm j .

Proposition 1 provides our primary result.

Proposition 1. Relative to the pre-merger situation, an exogenous merger between two firms increases the propensity of one of the post-merger firms to adopt the advanced technology, all other things being equal, up to a threshold level of higher marginal production costs of the advanced technology. At higher levels of marginal costs, the merger decreases the propensity to adopt.

Figure 2 illustrates this result using Cournot interactions. The vertical axis represents threshold fixed costs for adopting the advanced technology (i.e., the extra profit above production costs) and the horizontal axis measures impacts of the advanced technology on marginal production costs. The dashed line represents the duopoly case and the solid line represents a firm in a three-firm market. The vertical difference between the lines illustrates the difference in propensity to adopt the technology. If the advanced technology has no impact on marginal production costs, the advanced technology is more profitable for a duopolist than for a firm in a three-firm market, all other things being equal, implying a greater propensity to adopt the technology. The propensity diminishes as the impact on marginal production costs increases,

declining more rapidly for the duopoly market, with the result that the propensity is greater in the 3-firm market than in the duopoly market for sufficiently high marginal production costs.

[INSERT FIGURE 2 ABOUT HERE]

The merger can increase the incentives to adopt the advanced technology in two ways: (1) The merger increases the number of customers from which the adopting firm can recover the fixed costs of the advanced technology; and (2) The merger decreases competitive pressures, which allows firms to capture a greater portion of the economic value created by new technologies. We demonstrate this result by comparing operators' incentives to adopt the advanced technology in the pre-merger situation to the post-merger situation using Cournot competition. Figure 3 illustrates the pre-merger incentive. The vertical axis is firm 1's output and the horizontal axis is the sum of the other two firms' outputs. We sum the outputs of firms 2 and 3 for the horizontal axis so that the firms' choices can be shown on a two-dimensional graph. Outputs are expressed as numbers of customers served.

Figure 3 shows the firms' Cournot reaction functions.⁴ We show firm 1's reaction functions if it chooses to the standard technology or if it chooses the advanced technology. Choosing the higher quality shifts firm 1's reaction function upward relative to its reaction function with the standard technology. Thus for any particular output levels that firms 2 and 3 might choose, if firm 1 has adopted the more advanced technology, its output choice is higher relative to the amount it would have produced with the other technology. This shift represents the greater value that customers place on the advanced technology, less the production costs and adjusted for impacts of the demand elasticity and network effects. Firm 1's choice of technology does not impact the other firms' reaction functions with respect to their output.

[INSERT FIGURE 3 ABOUT HERE]

⁴ A firm's reaction function is its optimal output choice, taking the other firms' output choices as given.

The intersections of the reaction functions show the firms' equilibrium choices. If all firms choose the standard technology, the equilibrium output for firm 1 is \overline{AO} and for firms 2 and 3 together is \overline{CO} , which is twice firm 1's output because of assumed cost and demand symmetry. As is standard for Cournot competition in these types of models, a firm's equilibrium price is equal to its equilibrium output plus its marginal production cost, so firm 1's price is \overline{AO} , and the profit for firm 1 is simply its output squared, or \overline{AO}^2 , which is represented by the area of the square $ADEO$.

Now consider firm 1's incentive to adopt the more advanced technology in the three-firm market. We consider the intersection of firm 1's reaction function and firm 2's + firm 3's reaction function. The new equilibrium output for firm 1 increases to \overline{FO} and the combined outputs of firms 2 and 3 decreases to \overline{HO} , as do their prices. Firm 1's price increases to $\overline{FO} + c_1(H)$ and its profits are now its output squared minus its fixed costs, or $\overline{FO}^2 - f_1(H)$. Firm 1's revenue for the advanced technology in the pre-merger setting can be represented by the square $FIJO$, which illustrates that firm 1 could profitably adopt the advanced technology as long as the fixed cost is no greater than a threshold amount measured as the difference between square $FIJO$ and square $ADEO$, i.e., firm 1 will adopt the more advanced technology in the pre-merger setting if $FIJO - ADEO \geq f_1(H)$.

We are interested in how this incentive to adopt the advanced technology is impacted by decreasing the number of firms from 3 to 2, so we now turn our attention to technology adoption in the post merger setting illustrated in Figure 4. The vertical axis is the merged firm's output (firm m) and the horizontal axis is firm 2's output, given that firms 1 and 3 merged. The figure shows the firms' reaction functions.

[INSERT FIGURE 4 ABOUT HERE]

If all firms choose the standard technology, the equilibrium output for firm m is \overline{KO} and for firm 2 is \overline{MO} , which are equal because of our assumption in the figure of symmetric marginal production costs and demand. Each firm's equilibrium price is equal to its equilibrium output (because marginal production costs are zero) and each firm's individual profit can be represented by the area of the square $KLMO$.

Now consider the merged firm's incentive to adopt the more advanced technology. Figure 4 shows the new reaction function, which we label as "Firm m 's reaction function advanced technology." The new equilibrium output for firm m , \overline{NO} , is higher than before and the output of firm 2, \overline{QO} , is lower than before. Firm m 's price is higher ($\overline{NO} + c_m(H)$) and its profits are now its output squared minus its fixed costs, or $\overline{NO}^2 - f_m(H)$. Firm m 's revenue less production costs for the advanced technology in the post-merger scenario can be represented by the square $NRSO$, which illustrates that firm m could profitably adopt the technology as long as the fixed cost is no greater than the than a threshold amount measured as the difference between square $NRSO$ and square $KLMO$, i.e., firm m will adopt the more advanced technology in the post-merger setting if $NRSO - KLMO \geq f_m(H)$.

Figures 5a and 5b illustrate the non-linear tradeoffs between higher marginal production costs and the value of the advanced technology to customers. The z -axes measure the fixed cost thresholds, the x -axes measure the value of the technology to customers, and the y -axes measure the impact of the technology on marginal production costs. Each graph contains two planes. The blue plane represents the fixed cost threshold for a duopoly and the orange plane is the pre-merger setting. As one would expect, higher marginal costs mean that the advanced technology must have higher value to remain profitable. Comparing 5a and 5b illustrates the impact of

network effects. 5a does not include network effects, but 5b does. This leads to our first corollary.

[INSERT FIGURES 5a and 5b ABOUT HERE]

Corollary 1. Higher network effects increase the propensity for a firm to adopt the advanced technology.

Network effects increase the profitability of the advanced technology by increasing customers' willingness to pay for the network service. In the structure of the game, customers form expectations about network size before firms choose their outputs, creating an exogenous increase in willingness to pay from each firm's perspective. If customers created their expectations at the same time that firm's chose output in the game, the network effects would be indistinguishable from any other factor that make own-price and cross-price elasticities of demand more inelastic.

Proposition 1 and Corollary 1 imply that 4G technology adoption might have occurred at a faster rate had the U.S. competition authority not effectively blocked AT&T's acquisition of T-Mobile's U.S. assets, and that this increase in adoption could be greater because the firms are in a network industry. Network effects in this setting imply a reason for relaxing competition policy constraints on mergers.

Proposition 2 provides our next primary result, illustrated in Figures 6 and 7.

Proposition 2. Over a range of increasing marginal production costs for the advanced technology, all other things being equal, an exogenous merger:

1. Increases the propensity to invest in the advanced technology for all modes of competition with a sufficiently low increase in marginal production costs.

2. Bertrand competition provides the largest increase in the propensity to invest in the advanced technology, except over a narrow range in marginal cost increases, over which Cournot competition provides the greatest increase in propensity.
3. The propensity to invest in advanced technology becomes negative at lower increases in marginal production costs with Cournot interactions than it does with the other two modes of competition.
4. The propensity to invest in the advanced technology becomes zero at the same increase in marginal production costs for Bertrand and mixed competition.
5. The propensity to invest in the advanced technology increases throughout if the merger results in mixed competition moving to Cournot.

[INSERT FIGURE 6 ABOUT HERE]

Figure 6 shows how investing in the advanced technology for each form of competition. The vertical axis shows fixed cost thresholds for a duopoly minus those for a 3-firm market. The horizontal axis shows the possible changes in marginal production costs. The thick solid line represents Bertrand competition, which shows a greater profit impact than all other forms, except where the dashed line, representing Cournot competition, is higher over a small band of marginal cost increases. Bertrand and mixed competition have nearly identical differences in fixed cost thresholds. In Figure 6, the mixed competition scenario assumes that one of the firms in the duopoly is a price competitor.

[INSERT FIGURE 7 ABOUT HERE]

Figure 7 is like Figure 6 except that the blue line represents the effects of a merger that causes the loss of a price competitor such that, after the merger, the firms compete á la Cournot. In this scenario, the profitability of Cournot competition compared to any other form of

competition causes the relative propensity to invest in the advanced technology to grow even as marginal costs grow. This does not mean that the firm would actually adopt the advanced technology; rather it means that at higher levels of marginal production costs, adoption in Cournot competition is more profitable than with mixed competition.

[INSERT FIGURE 8 ABOUT HERE]

Figure 8 illustrates Figure 6's scenarios, but assuming that the merging firm with the small market share is small because it offers lower quality than the other firms. This assumption slightly lowers the impact the merger has on propensity to adopt the advanced technology for Cournot and Bertrand competition because the firm being absorbed was not a significant competitor in the 3-firm market. This assumption causes the impact on the propensity to become negative at lower marginal production costs for Cournot, but not for the other forms of competition. The assumption of the loss of a low-quality rival has a larger impact with mixed competition than with the other forms of competition, namely the difference in the propensity to adopt the advanced technology increases several fold at low marginal production costs. This occurs because the price competitor has changed from a low-quality competitor to a high-quality competitor.

It is unclear how Figure 8 impacts the argument that AT&T's acquisition of T-Mobile's U.S. assets could have sped the adoption of 4G technology. The impact on the propensity to adopt the technology is lower with Cournot and Bertrand competition when the smaller rival has lower quality, but is greater with mixed competition if AT&T had been able to incorporate T-Mobile's pricing strategies while remedying T-Mobile's quality issues and converting the T-Mobile customers' preferences for T-Mobile to preferences for AT&T.

The forgoing analyses also have implications for the GE-Honeywell case by supporting the notion that, to the extent that there were any horizontal aspects to the merger (which may not have been the case), the EUCC was right that the combined companies were more likely to adopt a higher quality product than the pre-merger companies. Even if that were not the case, if the merged company had a lower fixed cost threshold for adopting a new product – which appears to be close to the EUCC’s argument – then the forgoing analyses would still be supportive of the EUCC’s conclusion about product development by the merged entity. However, this is not to say that the EUCC’s second step in its analysis, namely that the merged entity’s better products would not be matched by rivals, bears up under our analysis.

We now turn our attention to how a merger impacts other firms’ incentives to choose the more advanced technology. Proposition 1 applies to all firms. But we would also like to know how the merger resulting in technology adoption by one firm impacts incentives for a second firm to also adopt the advanced technology. This leads to Proposition 3.

Proposition 3. Adoption of the more advanced technology by one firm increases the incentives for another firm to also adopt the more advanced technology.

We demonstrate this result with simulations. Figure 9 shows the simulation results. The vertical axis represents the net effect on fixed cost thresholds of adopting the advanced technology in a duopoly market, given that one rival has already adopted the technology. The effects are positive up to reasonably large increases in marginal production costs. In contrast to the scenarios where the rival had not adopted the advanced technology, for example, Figures 6-8, Figure 9 shows that the incentive to adopt increases once a rival has adopted. Also in contrast with the other scenarios, the increase in propensity is highest and most enduring with Cournot competition and lowest with Bertrand competition.

Proposition 9 implies that the EUCC could have erred in its conclusion that rivals could not have matched GE-Honeywell's higher quality products. The pre-merger economics of matching advanced technologies are not as attractive as the post-merger economics.

[INSERT FIGURE 9 ABOUT HERE]

V. Conclusion

In this paper we examine how a merger impacts adoption of advanced technologies. We find that despite the conclusions of a traditional horizontal merger analysis that a merger in a concentrated market harms customers, a horizontal merger where technology advancement is of interest can make customers better off by increasing the likelihood of advanced technology adoption. The merger makes the advanced technology more profitable by increasing the number of customers that can cover the fixed costs of technology adoption and by increasing the adopting firm's ability to extract economic rents from the adoption. Results vary with the type of competition. In general Bertrand competition provides the greatest incentive for a firm to adopt the technology if no other firm has, but Cournot competition provides the greatest incentives for a second firm to adopt the technology.

Appendix A

This appendix describes our simulations. We use Mathematica to perform the simulations and draw some of the graphs. In our base case, we arbitrarily assign $A = 10$, $a_1(H) = a_2(H) = 2$, $a_1(L) = a_2(L) = 0$, $c_i(L) = 0$, $b_{i,i} = 0.3$, and $b_{i,j} = 0.1$ for $i \neq j$. When network effects are considered, we assume $v = 0.05$. We assume the marginal production costs of the advanced technology are $a_1(H) = 1$ in the case where we test a second firm's reaction to adoption by firm 1. When we test the effects of a low-quality rival, we assume $a_3(L) = -3.5$.

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Figures

Figure 1. Duopolist Reaction Functions in Cournot, Bertrand, and Mixed Competition Expressed as Prices

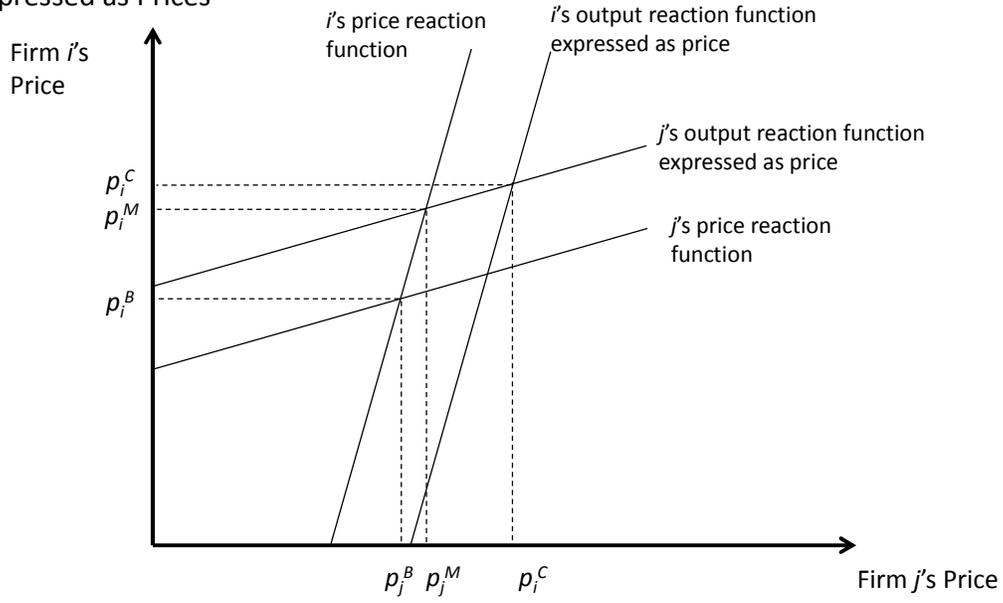


Figure 2. Comparison of Threshold Fixed Costs with Cournot Interactions and Varying Marginal Costs

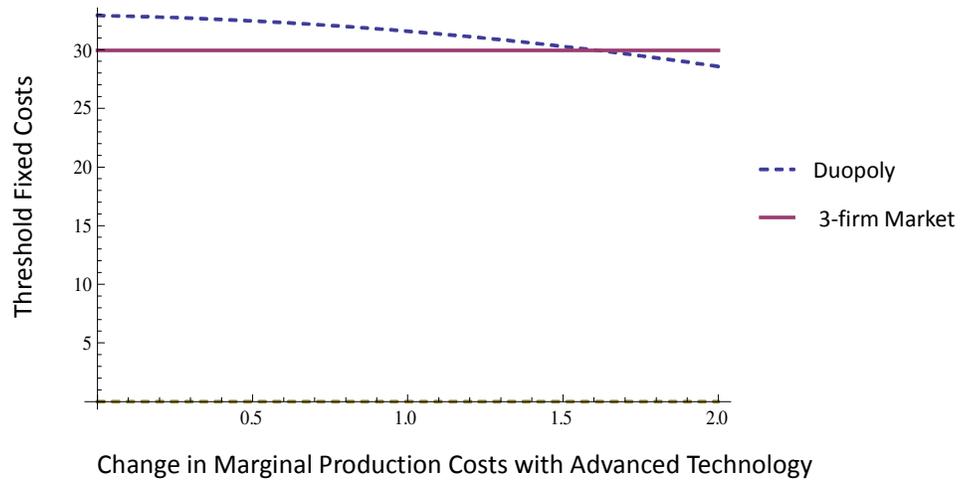


Figure 3. Impact of Single Firm Adopting Higher Technology in 3-Firm Market

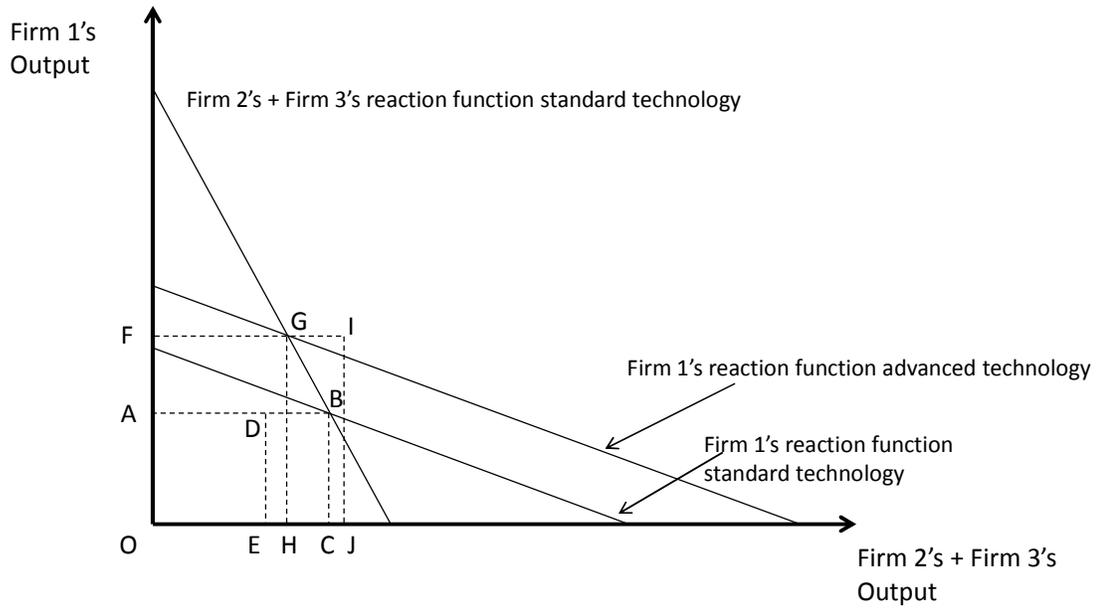


Figure 4. Impact of Single Firm Adopting Higher Technology in 2-Firm Market

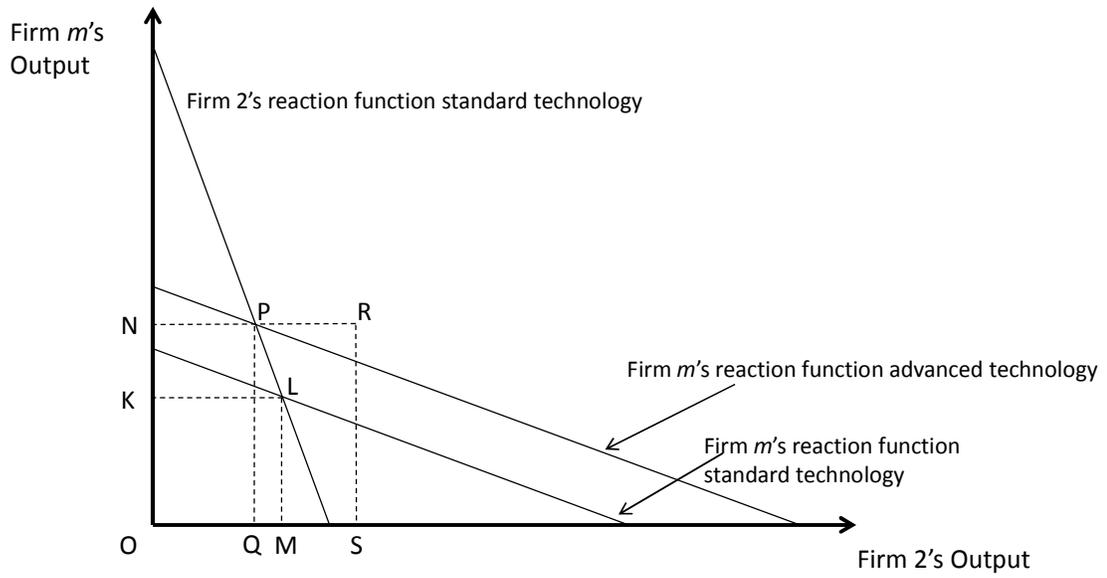


Figure 5a. Comparison of Pre-Merger and Post Merger Technology Adoption, Marginal Costs vs. Value of Technology, with Cournot Interactions and no Network Effects

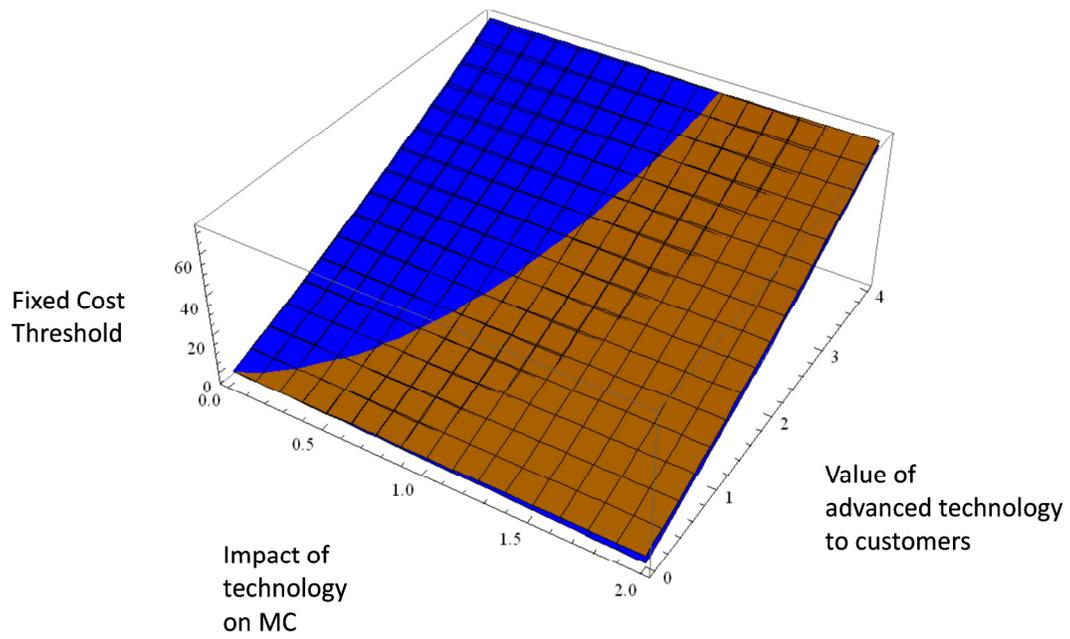


Figure 5b. Comparison of Pre-Merger and Post Merger Technology Adoption, Marginal Costs vs. Value of Technology, with Cournot Interactions and Network Effects

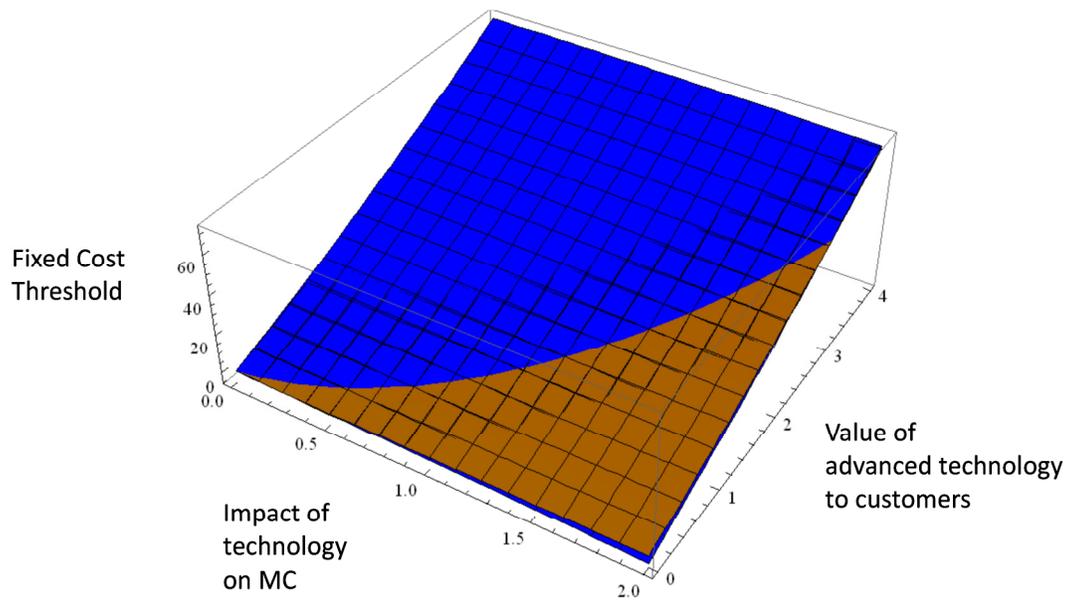


Figure 6. Comparison of Pre-Merger and Post Merger Technology Adoption vs Marginal Costs, No Network Effects

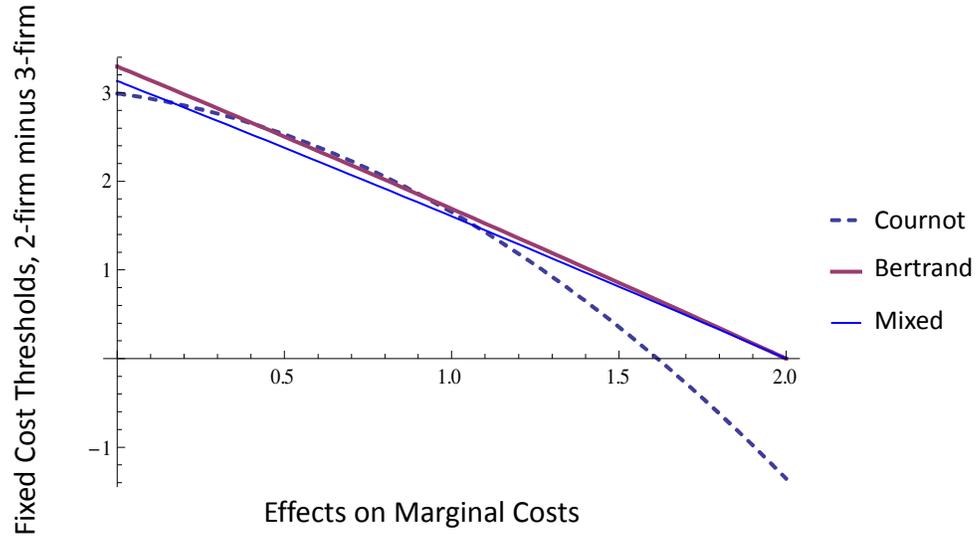


Figure 7. Comparison of Pre-Merger and Post Merger Technology Adoption vs. Marginal Costs, No Network Effects

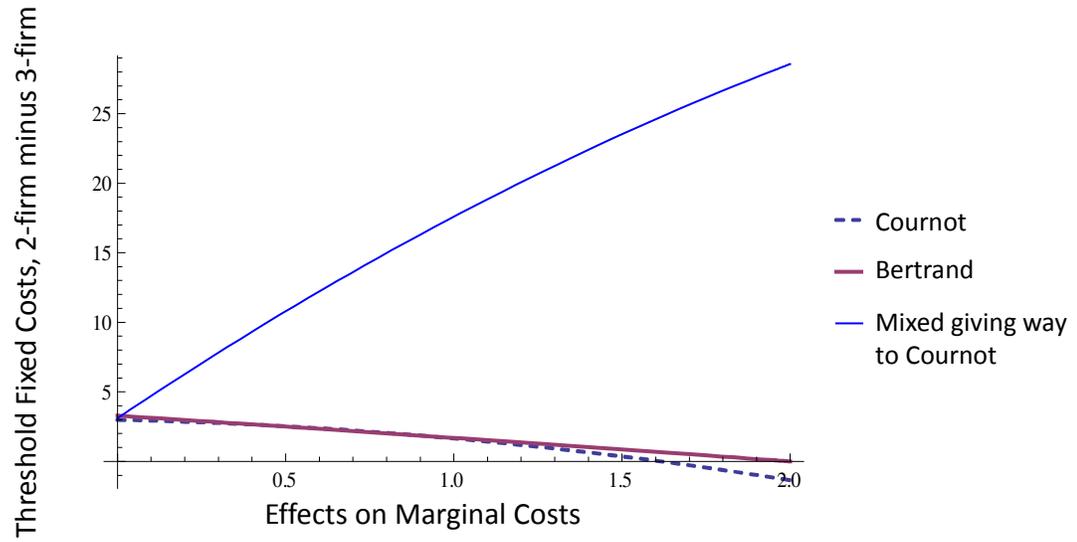


Figure 8. Comparison of Pre-Merger and Post Merger Technology Adoption vs Marginal Costs, No Network Effects, with low-quality rival

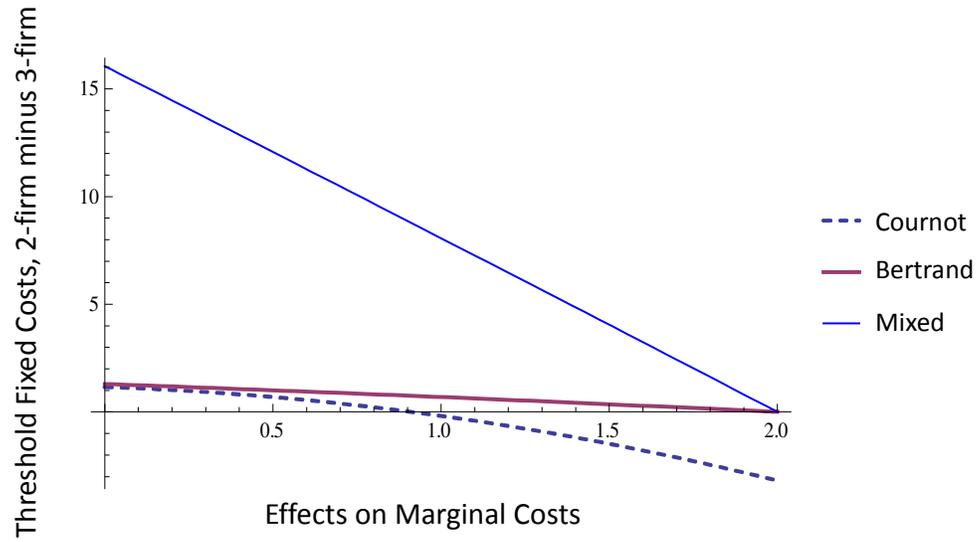


Figure 9. Comparison of Technology Adoption vs. Marginal Costs, No Network Effects, for Duopoly where Rival has Upgraded

