

Forthcoming, **COMMUNICATIONS & STRATEGIES**,
no. 85, 1st Q. 2012

Migration to the Cloud Ecosystem: Ushering in a New Generation of Platform Competition

Chaim Fershtman and Neil Gandal#

Abstract: Cloud computing is defined to be Internet based computing technology, where the term 'cloud' simply means Internet – and cloud computing refers to services that are accessed directly over the Internet. There are essentially three categories of cloud computing. (i) IaaS (Infrastructure as a Service) – number crunching, data storage and management services (computer servers), (ii), SaaS (Software as a Service) – ‘web based’ applications, and (iii) PaaS (Platform as a Service) – essentially an operating system in the cloud. Much of the attention and literature has focused on the revolution in IaaS services provided via the cloud. Despite the major changes in technology in IaaS services, estimates indicate that more than 90% of the cloud computing market (in terms of revenues) will involve (virtual) operating systems and applications software services (i.e., PaaS and SaaS services.) In this paper, we examine how several key economic factors will likely affect competition in SaaS/PaaS services in the cloud.

#Fershtman: Department of Economics, Tel Aviv University, Tel Aviv, 69978, ISRAEL and CEPR, fersht@post.tau.ac.il , Gandal: Department of Public Policy, Tel Aviv University, Tel Aviv, 69978, ISRAEL and CEPR, gandal@post.tau.ac.il. We are especially grateful to two anonymous referees, whose comments and suggestions greatly improved the paper. We are also grateful to Jacques Lawarree, Nick Tslias, and an anonymous engineer, and to participants at the round table on cloud computing at the Economics of the Software and Internet Industries conference, Toulouse, France (2011) for very helpful comments and suggestions. An academic research grant from Microsoft is gratefully acknowledged. Any opinions expressed are those of the authors.

Key words: cloud computing, platform competition, network effects, two-sided markets

JEL codes: L13, L86

1. Introduction

Cloud computing is defined to be Internet based computing technology, where the term 'cloud' simply means Internet – and cloud computing refers to services that are accessed directly over the Internet. Cloud computing is the new buzz word in the information technology world – and some have described it as nothing short of a revolution that will dramatically change that world. From a technical point of view, cloud computing is clearly a revolution. A 'cloud' data server farm or cluster is a collection of computer servers maintained by a cloud provider to provide computing services on a massive scale. This scale can be used both for data storage and management services as well as providing software services.

Cloud computing services will be available from any device (personal computer, tablet computers, mobile devices, etc.) that connects to the Internet. This is because cloud computing technology infrastructure is NOT based on consumer premises. As of 2009, 70% of Americans already used some type of cloud service – mainly web based email.

Like the variety of cloud formations up in the sky, cloud computing comes in many shapes, forms, and sizes. And consistent with that metaphor, cloud

computing means several quite different aspects of computing. There are essentially three aspects of cloud computing, two of which are quite related.¹

- IaaS (Infrastructure as a Service) – number crunching, data storage and management services (computer servers).
- SaaS (Software as a Service) – ‘web based’ applications (like Gmail).
- PaaS (Platform as a Service)² – essentially an operating system in the cloud like Google *AppEngine* and Microsoft *Azure*.

According to Forrester research as quoted by the Economist,³ the first category (IaaS) generated sales of approximately \$1 Billion in 2010. This category provides data storage, data management, and manipulation of large databases. Amazon is the dominant firm in this market, with a market share of 80%-90%. The second category (SaaS) generated revenues of \$11.7 Billion in 2010, while the third category (PaaS) generated \$311 Million of revenues.⁴ But these two categories are essentially part of the same market, since operating systems have virtually no stand-alone benefits and the value consumers place on operating systems increases in the number of compatible applications that run on the operating systems. Further, the dominant firms – Microsoft and Google – with (virtual) operating systems in this market provide most of the important in-house applications available (i.e., office suites like Microsoft Office and Google Docs.)

¹ These definitions are the ones that are typically employed when discussing the different layers of the cloud. See ‘Tanks in the Clouds, the Economist Online: 29.10.2010.

² Our use of the term ‘platform’ does not necessarily refer to two-sided market. Platform in this context means firms that have the ability to offer operating system and application software.

³ See ‘Tanks in the Clouds, the Economist Online: 29.10.2010.

⁴ Ibid.

The revenues of the PaaS/SaaS market are expected to grow to \$52 Billion in 2020, while the revenues of the IaaS market will only grow to \$4 Billion by 2020.⁵ This is in large part due to the fact that the cost of computer hardware (infrastructure) will continue to drop. This trend is similar to what happened in the personal computer market. Like the personal computer market, the IaaS market is characterized by relatively homogenous goods; hence it is likely that it will be subject to intense price competition and low profitability. In the PaaS/SaaS market, on the other hand, the products are potentially quite heterogeneous and we expect greater consumer loyalty. Thus while the technical innovations have enabled low-cost, large-scale data storage and data management in remote servers, the (Forrester Research) estimates cited above indicate that this part of the market (infrastructure services) will make up less than 10% of the cloud computing market. More than 90% of the cloud computing market (in terms of revenues) will involve (virtual) operating systems and applications software services (i.e., SaaS and PaaS services.)

There are several important 'economic' aspects of cloud computing that will affect the competition in SaaS/PaaS (platform) the market. Arguably, the two economic aspects that will have the most profound implications for the development of cloud computing are (I) changes in the strength of network effects and (II) the organizational model that emerges, i.e., whether cloud computing will retain its current 'conduit' and vertically integrated structure or whether it will develop into a two-sided market:

⁵ Ibid.

(I) Network Effects in Cloud Computing: Since application software programs are typically compatible with a specific operating system, network effects played a major role in determining the type of market equilibrium.⁶ In particular there were very strong network effects in operating systems in on-premise markets: consumers preferred to use operating systems that were readily available on many computers (direct network effect) and also an operating system that offered a large variety of application software (indirect network effect), while software developers preferred to develop software for operating system with many users. These effects often led to a setting where a single firm won the battle among standards.

The transition to the cloud will affect the strength of the (direct and indirect) network effects of the virtual operating systems and will therefore likely change the pattern of competition in the market, as well as the equilibrium outcomes. In particular, indirect network effects will likely be weaker for the operating systems in the cloud environment. This will make it more likely that multiple platforms can exist in equilibrium in the cloud. Hence de-facto standardization on one platform seems less likely in competition among cloud platforms than in the case of competition among on-premise platforms. We discuss this issue further in section 3.

(II) Organization and Evolution of Cloud Markets: How might cloud computing markets be organized? Will cloud computing evolve into a *two-*

⁶ Seminal contributions in the economics literature on direct network effects are papers by Farrell and Saloner (1985,1986) and Katz and Shapiro (1985,1986) that examine the social and private incentives to achieve compatibility/standardization. Chou and Shy (1990) and Church and Gandal (1992) examine similar questions in settings with indirect network effects.

sided market,⁷ or will it remain a vertically integrated system? Currently, the two main platform owners (Microsoft and Google) supply the critical complementary software (email service, office productivity suites) for their platforms in order to attract consumers. We discuss this issue in section 4.

Other key economic issues include:

Different Pricing Models: Users may rent 'cloud' software, rather than purchase it. In an on-premise setting, a user had to buy (license) the software in order to use it. The payment was independent of usage and the license was typically valid as long as the consumer used the software on his PC. This will likely change when we move to the cloud ecosystem. Users will likely pay for software according to their usage; this is equivalent to renting the software. Clearly selection will be such that heavy users will continue to buy the product while others will rent it. This will affect the pricing of cloud software services. Pricing will also be affected by whether key services are bundled as they were in on-premise competition (i.e., Office Suites.) This issue is discussed in section 4.

Compatibility and Standards: An additional key issue involves compatibility, in particular whether it is feasible for entrants to achieve one-way compatibility with an established standard. (One-way compatibility means that the software written for the incumbent technology can be used on the entrant's technology.) With the network advantage enjoyed by the incumbents, entry may not be possible without compatibility with one of the incumbent platforms. This strategy is especially relevant in the cloud

⁷ See Armstrong (2006), Rochet and Tirole (2006) for an introduction to two sided markets.

ecosystem because compatibility is easier to achieve and less costly. We discuss this issue further, as well as discussing developments in standards in cloud computing in section 5.

Cyber Security: As virtual operating systems and online software become more prominent, security issues will become paramount. Many computers have been and are infected with spyware and viruses via the Internet. Engineers and computer scientists have expressed concerns of an increase in security breaches (Molnar & Schechter 2010) as the industry switches from in-house computing to the services offered by cloud providers. See section 6.

There is virtually no research on the economics of cloud computing. The literature that exists has primarily focused on the technical aspects of cloud computing. Ambrust et al. (2009) is an excellent source for understanding the development of cloud computing and issues related to data storage management, computation and related services (i.e., IaaS services.) Another branch of the developing literature (e.g. Etro, 2009) focuses on the macroeconomics changes (creation of jobs, changes in output, etc.) from the introduction of cloud computing technology.

In the following section, we discuss of the current state of competition among cloud providers of SaaS and Paas services. In sections 3-6 we examine how the factors discussed above will affect competition in the Paas/SaaS cloud computing market. Section 7 briefly concludes.

See Rysman (2009) for a detailed survey of the literature on two-sided markets.

2. Current State of Competition in PaaS/IaaS software services in the Cloud

Two firms, Microsoft and Google, already have well established platforms in the cloud: Microsoft Azure and Google AppEngine.⁸ Microsoft and Google also both have large installed bases on users. But their installed bases come from different sources. In the case of Microsoft, the installed base comes from the large number of premise-based users, and the popularity of its very successful on-premise *Office Suite*, which consists of a word processor, a spreadsheet and a presentation software package. In the case of Google, the installed base comes from the cloud itself, in particular from users of Gmail, the Google email system.⁹

Installed base is important because it affects current and future network effects and makes it easier for platforms to offer new (compatible) services to existing users than it is to convince new consumers to join the platform. Installed base is also important because most consumers do not switch immediately when new platforms are offered. Installed base will be less important if all key services are fully compatible across platforms. In such a case, consumers will be able to mix and match.

⁸ Amazon is major player in cloud computing as well, but it primarily operates in the IaaS market.

⁹ Microsoft also provides cloud email server services via its Exchange Server.

Microsoft and Google also have provided software applications for their cloud platforms. In the case of Microsoft, the in-house applications for the on-premise Windows operating system are offered online via Microsoft Azure as well. These applications include Microsoft Office. The on-premise operating system (Windows) is compatible with the 'cloud' operating system (Azure.) This means that all office software files (word processors, spreadsheets, and presentation software) created 'on premises' can be edited on the cloud as well, and vice versa. Edited files are automatically synced between the Cloud and the on-premise environment.

Google, in-house applications include 'Google Docs,' an online version of an office suite that consists of a word processor, spreadsheet, and presentations software program that works on the Google AppEngine platform. Google Docs can be accessed by all users with a Gmail account. Users can create the documents, spreadsheets, or presentations within the application or it can be imported from other formats and converted to 'Google Docs' format. The documents are then saved to Google's servers, but they can also be saved to a user's computer. The service runs on most web browsers. Google Docs 'documents' can be shared – and they can be viewed and edited by multiple users in real-time simultaneously.

3. The Importance of Network Effects in the Cloud

Similar to 'on premises' platforms, *direct network effects* exist in the Cloud because users want to share documents, files, projects, data, and other information. For example, R&D managers and project members want to be able to share and jointly edit documents related to the research project.

Another example of direct network effects in the cloud involves online calendars. Family members (or friends) who are on the same online platform can share their calendars with each other – and instantly see the scheduling updates made by their contacts. 'Cloud computing' social networks like Facebook, Twitter, LinkedIn, etc., are also such that the benefit from being a member increases in the number of friends/contacts.

Indirect network effects exist in the Cloud as well. Similar to 'on premise' operating systems, online platforms (virtual operating systems) are not valuable without complementary software.

The key differences (regarding network effects) between the on-premise world and the cloud are manifested at the operating system level. There are two important differences regarding indirect network effects for operating systems between clouds and on-premise platforms: First, data in application software programs are more likely to be portable across operating systems as the following example illustrates:¹⁰

Example 1:

- *On Premises:* I chose Windows because I use the machine for my hobby and I know someone has to make software for that hobby that runs on Windows. I don't want to start with a Mac and then have to buy a Windows machine anyway to run my hobby software.
- *In the Cloud:* I like Google Maps, but I like the word processor from *Live*. I cut the Map from Google and pasted

¹⁰ We are grateful to an anonymous engineer for examples 1 and 2, and the related discussion.

it into the document open on *Live*. I have to keep two passwords, and sometimes I have to download data, but otherwise I don't care.

Secondly, on the desktop, consumers typically benefited only from software applications written for the operating system they employ. In order to benefit from applications software programs written for other operating systems, consumers typically had to switch platforms (operating systems) or add an additional operating system. The consumer switching cost was quite high and in practice few consumers were willing to incur it in order to benefit from an applications software program written for another operating system.¹¹ Things are quite different in the cloud as the following example illustrates.

Example 2:

- *On Premises:* Suppose an applications software firm had 10,000 consumers using their application on a Windows operating system, but they wanted to switch to Linux. After they would port their application to Linux, they would have to convince the 10,000 consumers to install Linux. This is a time consuming and costly process for the consumer and it will typically cause incompatibility with the consumers' other existing applications, which run on Windows.
- *In the Cloud:* Now suppose that the same company has an Azure application with 10,000 users and they want to switch to Google Application Engine. They still have to port their software, and move the user data over, but the users may never know that the platform has changed. Thus the total cost of the 'change,' both for consumers and firms could be many orders of magnitude smaller.

¹¹ See Farrell and Klemperer (2007) for a review of the literature on network effects and switching costs.

Example 2 illustrates that in the cloud, platform switching costs for developers moving from one cloud to another (say from Microsoft Azure to Google Application Engine) are about the same as desktop software (Windows to Apple). At the consumer level, however, there is little or no switching cost in the case of cloud-based applications. The switching costs for changing platforms are incurred only at the server level, and the consumer may not know (and definitely does not care) that the underlying operating system has been changed. Because applications programs are accessed directly via the browser, 'compatibility' among software applications written for different operating systems will exist in the cloud to a much greater extent than in the on-line markets.

These differences will reduce the strength of indirect network effects for the operating systems and make it more likely that multiple platforms can exist in equilibrium in the cloud. Hence de-facto standardization on one platform seems less likely in competition among cloud platforms than in the case of competition among on-premise platforms.

4. Organization of Cloud Software Markets and Possible Pricing Models

Here we briefly discuss how Cloud software markets might be organized and pricing models that might evolve in the Cloud. It is important to note that Cloud computing is currently not a *two-sided market*, since the platform owners (Microsoft and Google) supply the critical complementary software

(email service, office productivity suites) for their platforms in order to attract consumers.¹²

At this stage, Cloud computing is similar to Cable television service in many respects. Like the cables that bring content into a consumer's home, the Cloud is also a conduit. Further, in the cable industry, there is a great deal of vertical integration between the owner of the conduit and the content providers.¹³ As noted, the major Cloud computing firms are vertically integrated into the provision of key software services. In settings with vertical integration, there is not a two-sided market, since the conduit provider also provides the applications software as well.

Another form of organization in the cable market is when the infrastructure provider purchases channel services from an independent content provider for a fixed fee. Here there is a question of pricing, but the market is again not two-sided. This is because, once the price of the channel has been determined, there is no network effect on the content side of the market.

An alternative structure is when the cloud platform providers only offer the infrastructure, i.e., like a shopping mall. This form of organization is indeed a two-sided market. In such a setting, there is a platform owner who

¹² To understand two-sided markets, consider the Visa platform. Consumers will not be willing to hold and pay for Visa cards unless they are widely accepted by merchants. Similarly, merchants will not be willing to honor credit cards and pay a fee to the platform if the cards are not widely held by consumers. This is an example of a two-sided market, since Visa must choose prices on both sides of the market (consumers and merchants) in order to overcome the chicken-egg issuer and insure that both sides of a market will be willing to use the platform. Two-sided markets are markets that exhibit indirect network effects on both sides of the market.

may charge independent software developers fees in order to be able to provide their service via the platform owner's proprietary cloud. While the fee may have a fixed component, it also may depend on the number of consumers subscribers who use the cloud. In this case, pricing has all the standard issues associated with two sided markets.¹⁴

The structure that will likely emerge is dependent to a great deal on whether third party sources of complementary products become essential for the success of the platform. In settings in which third-party provision is important, firms that do not open their platforms to third party providers and create incentives for these firms to provide software applications for their platform often fail when competing in platform completion. Sony, for example, lost the Beta/VHS format war because of the dearth of movies available for its platform.¹⁵ Currently, as noted above, the main providers of cloud operating system services provide the key applications software themselves.

Finally, will other proprietary clouds be able to offer software from Microsoft and Google? In other words, will it be possible for another cloud platform to offer these services to end users. This would fundamentally change the dynamics in the market and increase the likelihood that several cloud platforms could exist in equilibrium. Currently, access to clouds is free and users pay according to the software they use. In this environment, users may access different clouds for different services. One possible development is that clouds would charge access or membership fees. This

¹³ See Crawford and Yurukoglu (forthcoming, 2012).

¹⁴ See for, example, Armstrong (2006) and Rochet and Tirole (2006).

¹⁵ See Ohashi (2004).

would be possible if clouds would carry similar types of software as discussed above. Such a payment would affect the competition between cloud platforms as individuals would prefer to get all their software services from the same cloud.

5. Compatibility and Standards

A key question is whether a new entrant can (in a cost effective manner) achieve one-way compatibility with an established standard so that software written for the incumbent technology can be used on the entrant's technology. With the network advantage enjoyed by the incumbents, the only way to enter the market may be for the entrant to attain compatibility with one of the incumbent platforms. If files can be saved in a common format across platforms, users benefit from network effects despite being on different platforms and compatibility insures that purchasers of the entrant technology will not be orphaned.

One-way compatibility is especially relevant in the cloud ecosystem because, as discussed in example 2 above, compatibility across operating systems is less costly. This strategy has already been adopted in the cloud ecosystem, both in the applications software level, as well as at the operating system level:

One-way compatibility – applications software layer: Beyond the similarities between Microsoft and Google, (large installed bases, cloud operating systems, and office productivity suites), there is a fundamental

asymmetry that has affected the way competition between the platforms has evolved. Given the popularity of *Microsoft Office*, Google has adopted a 'compatibility' strategy. Although early versions of the Google office suites were quite primitive, Google Docs was able to import files in many formats including Microsoft formats such as Excel, Word. Nevertheless, compatibility was not full and many files lost functionality and formatting. That changed when Google acquired a company that developed a converter, which was renamed '*Google Connect for Microsoft Office*.' The plug-in enables Microsoft Office users to use the Office interface – and sync their on-premise *Office* documents in the Google Cloud. They can do this from within Microsoft Office and these 'documents' can also be viewed and edited by multiple users in real-time simultaneously. Changes are automatically synced.¹⁶ Hence, Google has essentially achieved one-way compatibility in this market.

One-way compatibility – operating system layer: Other 'platforms' are entering the market by employing one-way compatibility. 'Glide,' for example, is an online platform that offers email services, office suite software, and other software services. Glide's applications software products are compatible with the dominant platforms: its software runs on all three of the major desktop computing platforms: Windows, Linux, and Apple (Macintosh). Additionally, Glide software is also compatible with virtually all 'smartphone' platforms in order to attract users who access the Internet from cellular phones. In the case of Glide, compatibility across desktop and mobile platforms means that documents edited online will be updated on the Desktop (or Mobile) and vice-versa. By ensuring compatibility with the

¹⁶ <http://tools.google.com/dlpage/cloudconnect?hl=en>.

dominant platforms, Glide increases its chances of being able to compete despite a much smaller installed base.¹⁷

While one-way compatibility may help entrants, standardization is important for all cloud providers. This is because competition in platform markets may entail high risks for firms. First, the firm may lose the standards war. As noted, Sony lost the standards war in the VCR market to VHS.¹⁸ Secondly, fragmented expectations may lead to the failure of all competing platforms. Postrel (1990) partly attributes the failure of quadrasonic sound in the 1970s to competing standards. Hence, firms may be willing to have a single standard set “outside” of the marketplace. The DVD (digital video disc) industry provides an example of a jointly developed standard. In order to avoid another Beta/VHS format war, hardware manufacturers led by Sony, Toshiba, and Panasonic, and movie studios, led by Warner and Columbia (a division of Sony), worked together to establish a single standard.¹⁹

Since cloud computing is still in its infancy, standards are also in the formative stage. The importance of the development of standards for cloud computing can be seen by the large number of SSOs/SDOs working on cloud standard development. These include major SDOs like the European Telecommunications Standards Institute (ETSI) and the National Institute of

¹⁷ See "Glide OS connects across devices, desktops," by Seth Rosenblatt, April 23, 2009, Cnet Dowland.com, http://download.cnet.com/8301-2007_4-10226515-12.html.

¹⁸ Following the unsuccessful battle in the VCR market, Sony purchased Columbia Pictures in order to guarantee software (music, movies) supply for its electronic goods platform. Although an 'integration' strategy is helpful in platform competition, it typically is not enough to guarantee success.

¹⁹ See Dranove and Gandal (2003).

Standards and Technology (NIST).²⁰ Further, the Telecommunications Industry Association (TIA) recent issued a 'white paper' on cloud computing. The primary purpose of the 'white paper' is to address compatibility issues between TIA standards and cloud standards.²¹

6. Cyber Security in the Cloud

As virtual operating systems and online software become more prominent, security issues will become paramount. This is because many computers have been and are infected with spyware and viruses via the Internet. Some of the viruses have caused severe damage and have been very costly. According to the *Economist* magazine the Blaster worm and SoBig.F viruses of 2003 resulted in \$35 Billion in damages.²² More recently, "Botnet" programs – sophisticated programs that install themselves on unprotected personal computers – have enabled attackers to link infected computers into networks that steal data, as well as money from online bank accounts and stock brokerages.²³

There is a nascent literature at the "intersection" of computer science/engineering and economics on cyber security. Much of the work in the field has been undertaken by computer scientists and has led

²⁰ See http://cloud-standards.org/wiki/index.php?title=Main_Page

²¹ See http://www.tiaonline.org/standards/TIA_Cloud_Computing_White_Paper.pdf .

²² See "Internet security: Fighting the worms of mass destruction, *Economist*, Nov 27, 2003, available at http://www.economist.co.uk/science/displayStory.cfm?story_id=2246018.

²³ See "Google, citing Attack, Threatens to Exit China," by Andrew Jacobs and Miguel Helft, NY Times online, January 13, 2010, at <http://www.nytimes.com/2010/01/13/world/asia/13beijing.html>.

to some important insights into why information systems have become so insecure (see Anderson and Moore, 2006). Contributions by economists have primarily focused on (i) the lack of incentives for individuals or network operators to take adequate security precautions – see Varian (2004) and Camp and Wolfram (2004) among others – and (ii) the incentives for firms to disclose information about vulnerabilities (Choi, Fershtman & Gandal, 2010).

There is now a consensus in the literature that the improving Internet security involves more than just finding technical solutions. Indeed, The Slammer, Blaster, and Sobig.F viruses exploited vulnerabilities even though security updates had been released. That is, although the updates were widely available, relatively few users had applied them. This clearly illustrates that technical solutions alone cannot solve cyber security problems.

As the paradigm shifts so that more SaaS/PaaS services are provided online rather than on-premise, the exposure to such viruses and thus the potential for damage is even greater. Recently, engineers and computer scientists have expressed concerns of an increase in security breaches (see Molnar & Schechter 2010) as the industry switches from in-house computing to services offered by “public” (i.e., independent) cloud providers. An important question is how the industrial organization of cloud software markets affects the incentives of cloud providers to implement effective security. Additionally, the development of timely standards is also important because, in addition to the possible fragmentation issues (discussed in the previous section,) standards can improve security.

Summary Remark

Cloud computing is still in a very formative stage, and it is not possible to foresee how platform competition will develop. In this paper, we examined how key factors might affect the development of platform competition in cloud-based computing. Our goal was to raise economic issues that will likely affect the development of SaaS/PaaS services in Cloud Computing. Our analysis suggests that de-facto standardization on one platform seems less likely in competition among cloud platforms than in the case of competition among on-premise platforms. Further, it is not clear that cloud computing will develop into a classic two-sided market, but rather may remain a fairly vertically integrated industry with platforms providing both integrated (virtual) operating system and applications software.

References

Armbrust, M., Fox, A., Griffith, R., Joseph, A., Katz, R., Konwinski, A., Lee, G., Patterson, D., Rabkin, A., Stoica, I., and M. Zaharia, 2009, Above the Clouds: A Berkeley View of Cloud Computing, EECS Department University of California, Berkeley, Technical Report No. UCB/EECS-2009-28, available at <http://www.eecs.berkeley.edu/Pubs/TechRpts/2009/EECS-2009-28.html>

Anderson, R., and T. Moore, 2006, "The Economics of Information Security," *Science*, 314:610-613

Armstrong, M., 2006. "Competition in Two-Sided Markets," *The RAND Journal of Economics*, 37(3): 668–91

Camp, L., and C. Wolfram, "Pricing Security," in L.J. Camp and S. Lewis, eds., *Economics of Information Security*, vol. 12, *Advances in Information Security*. Springer-Kluwer, 2004.

Choi, J., Fershtman, C., and N.Gandal, 2010, "Network Security: Vulnerabilities and Disclosure Policy," *Journal of Industrial Economics*, 58:868-894

Chou, C. and Shy, O., 1990 "Network Effects without Network Externalities," *International Journal of Industrial Organization*, 8: 259-270

Church, J., and Gandal, N., 1992, "Network Effects, Software Provision and Standardization." *Journal of Industrial Economics*, 40: 85-104.

Crawford, G., and A. Yurukoglu, "The Welfare Effects of Bundling in Multichannel Television Markets," forthcoming, 2012, *American Economic Review*

Dranove, D., and N. Gandal, 2003, "The DVD vs. DIVX Standard War: Empirical Evidence of Network Effects and Preannouncement Effects," 2003, *Journal of Economics and Management Strategy*, 12: 363-386 (CITE)

Evans, D. ,2003, "The Antitrust Economics of Multi-Sided Platform Markets." *Yale Journal on Regulation*, 20: 325–82.

Etro, F., 2009, "The Economic Impact of Cloud Computing on Business Creation, Employment and Output in Europe," *Review of Business and Economics*, 54(2):179-208.

Farrell, J., and P. Klemperer, 2007, "Co-ordination and Lock-in: Competition with Switching Costs and Network Effects", in *Handbook of Industrial Organization* 3, M. Armstrong and R. Porter (eds), pps. 1967-2072.

Farrell, J. and Saloner, G., 1985, "Standardization, Compatibility and Innovation," *RAND Journal of Economics*, 16:70-83

Farrell, J., and G. Saloner, 1986, "Installed Base and Compatibility: Innovation, Product Preannouncements, and Predation." *American Economic Review*, 76:940–955.

Katz, M. and Shapiro, C., 1985 "Network Externalities, Competition, and Compatibility," *American Economic Review*, 75, pp. 424-440

Katz, M. and Shapiro, C., 1986 "Technology Adoption in the Presence of Network Externalities," *Journal of Political Economy*, 94, pp. 822-841

Molnar, D. & Schechter, S., 2010, "Self Hosting vs. Cloud Hosting: Accounting for the security impact of hosting in the Cloud," Workshop on the Economics of Information Security (WEIS), Harvard University, Cambridge, MA

Ohashi, H., 2004, The Role of Network Effects in the US VCR Market, 1978–1986, *Journal of Economics & Management Strategy*, 12:447-494.

Postrel, S., 1990, "Competing Networks and Proprietary Standards: The Case of Quadraphonic Sounds," *Journal of Industrial Economics*, 39: 169-185.

Rochet, J., and J. Tirole, 2006, "Two-Sided Markets: A Progress Report." The

RAND Journal of Economics, 35(3): 645–67

Rysman, M., 2009, "The Economics of Two-Sided Markets, *Journal of Economic Perspectives*, 23: 125-143

Telecommunications Industry Association, 2009, "White Paper on Cloud Computing," available at

http://www.tiaonline.org/standards/TIA_Cloud_Computing_White_Paper.pdf

Varian, H., 2004, "System Reliability and Free Riding," available at <http://www.ischool.berkeley.edu/~hal/Papers/2004/reliability>.