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Network to Net Worth

Exploring Network Dynamics

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- As networks increasingly dominate the business landscape, it is crucial for investors to understand network effects—how the value of a network increases with more users.
- Network effects can be classified along a spectrum, with stronger and weaker forms. As investors, we seek companies where network effects are strong and can be captured through superior financial performance.
- Networks offer the opportunity for explosive shareholder returns. Winners in the network competition collect a trio of benefits: accelerating sales growth, lower incremental cost, and a strengthened position of competitive advantage.
- Getting to critical mass is the key to network value. Beyond critical mass, growth becomes self-sustaining.

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Executive Summary

Networks have been around for a long time. But they are becoming a more significant part of the economic landscape for two primary reasons. First, the precipitous drop in communication and computing costs means that people are more connected than ever. As a result, networks can form more frequently, and at a faster rate, than ever before. Second, the global economy is rapidly changing from one based on physical assets to one based on intellectual assets. This shift has fundamentally and irrevocably altered the traditional links between sales and costs. The consequence is the creation of unprecedented amounts of shareholder value.

Key points are as follows:

- *Network effects.* Network effects exist when the value of a good increases because the number of people using the good increases. Network effects are also associated with Metcalfe's Law, which states that the value of a network grows exponentially as new members join arithmetically. As investors, we are looking for two things. First, we are looking for circumstances where network effects are *intense*. By definition, all networks have network effects. But they have them to varying degrees. The strongest forms of network effects hinge on two drivers: *interactivity* and *compatibility*. Second, we are looking for networks where a company—and hence its shareholders—can directly capture the benefit of network effects.
- *Successful networks can generate huge shareholder value.* Networks can generate sales in myriad ways. Often, the more successful a network, the *more* ways it can generate revenues. Networks based on intellectual assets have particularly interesting economic dynamics. Most intellectual assets businesses have high up-front and low incremental costs. So when a network reaches critical mass, its revenues grow at an increasing rate but its incremental costs stay negligible. Finally, we believe that networks offer a meaningful source of competitive advantage as a result of sizable aggregate switching costs.
- *Getting critical.* Biological analogies are useful when thinking about innovation diffusion. For example, a flu epidemic requires two things: interaction among people and contagiousness. In fact, epidemics and the diffusions of innovation both follow an S-curve. There are three things in particular to note about network formation. First, interactive innovations, including networks, grow at a faster rate than noninteractive ones. Second, an individual's adoption threshold is defined by what people near him or her do. Finally, the "small-world" effect shows us how communications technology makes us more connected to one another than ever before.
- *The rise of networks will affect everyone.* While networks are important in technology industries, they are not a phenomenon confined to the new economy. The eruption of business-to-business exchanges, many of which serve old-economy companies, is proof positive. These exchanges will profoundly transform the way business is conducted in the future. Traditional companies increasingly understand this change and are insisting on equity stakes in the new networks in return for their sponsorship and participation.

Introduction

If the dominant symbol of the industrial economy is a factory, then the emblem of the modern economy is a network. While interconnected systems have always existed, the digital revolution is fundamentally altering both network dynamics and network economics.

Physical networks, from traditional telephone to high-capacity fiber-optic systems, abound. But virtual networks also exist. And even though users in a virtual network are not physically linked, they greatly value the ability to interact. The one element that unifies all networks is that their value depends on the number of people connected to them.

This is known as a *network effect*. *A network effect exists when the value of a good increases because the number of people using the good increases*. All things being equal, it's better to be connected to a bigger network than to a smaller one. Adding new customers typically makes the network more valuable for *all* participants because it increases the probability that everyone will find something that meets their needs. So getting big fast matters, not only because it creates more value, but also because it assures that competing networks never take hold. With large industry coalitions announcing the formation of "eMarketplaces" almost daily, the issues of network formation and network value are more important than ever.

Networks have been around, in some form, for a long time. So what's the big deal? The big deal is that today's networks are commanding market values that are radically different than those of the past. This surge in value is attributable to a host of factors. First, the physical capital needs today are lower than prior periods. This lowering reflects not only a shift from tangible to intangible assets, but also the fact that the *cost of technology is declining*. Second, since most network formation costs are up-front, winning networks demonstrate increasing returns as they expand. Third, the staggering increase in computing and communication power mean that networks can form more frequently, and faster, than ever. Finally, networks can quickly spread globally owing to extraordinary scalability.

How did Yahoo! blossom to a $70 billion company with over 120 million users in just five years? Why is Sabre, an Internet travel and reservations company, awarded a market value that currently exceeds the combined market capitalization of three prominent airlines? And why do some business-to-business hubs have valuations that exceed the entire productive output of their respective vertical industries?

The goal of this report is to answer these questions. We address the issue in three parts. First, we explore some basic network dynamics, including the concept of network effects and where they are most prominent. Second, we discuss networks and economic value, touching on the sources of value creation, the economic characteristics of networks, and how they serve as a source of sustainable competitive advantage. Finally, we study the key issue of network formation in an attempt to understand how and why certain networks emerge as dominant.

The Wonderful World of Network Effects

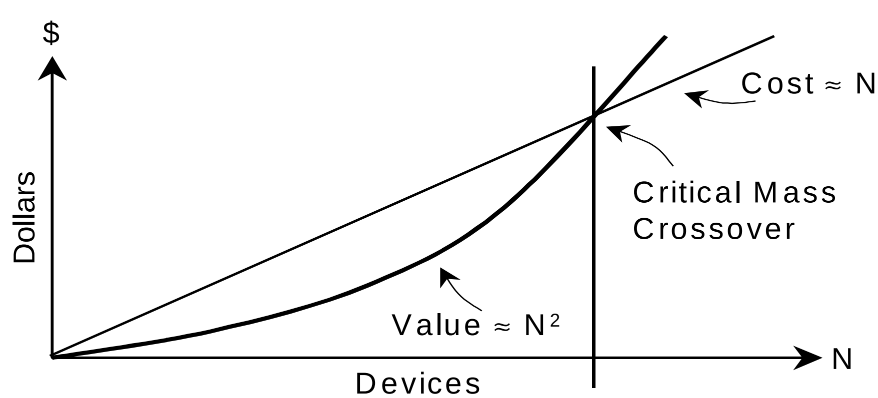
To illuminate the power of doubling, grade school children are often told the story of the Chinese Emperor so enamored with chess that he granted its inventor any wish. The erudite chess master requested that one humble grain of rice be placed in the first square of the chessboard on the first day, two meager grains on the second, four tiny grains on the third, and so on, until all sixty-four squares were filled. (Once accomplished the inventor would collect the sum.) Little did the emperor know that granting the inventor's wish would force him to cede a great deal more than he had the power to give. Assuming all the squares were reached, over 18.4 quintillion grains of rice would overflow the board. At a density of ten grains per square inch, the rice would actually cover the entire surface of the earth![1]

Interestingly, by the time the midpoint on the board is reached—the 32nd square—only 4 billion grains of rice have amassed, or about enough to cover a half-acre of land. The full power of the exponential process is only realized during the second half of the story. So what does this tale have to do with networks?

Plenty, as it turns out. Twin exponential processes, which are just beginning to hit their stride, are fueling today's economy. Technology guru George Gilder calls them the Law of the Microcosm and the Law of the Telecosm. The first states that computer processing power doubles every 18 months. This is commonly known as Moore's Law.[2] It is estimated that we reached the 32nd doubling of computer power back in 1995.

The second is the Law of Telecosm, also powerful but not as well understood. It says that the value of a network grows exponentially as nodes are added arithmetically. This force is also known as Metcalfe's Law, named after Bob Metcalfe[3], inventor of Ethernet and founder of 3Com. In Metcalfe's words, "When you connect computers together, the cost of doing so is n, but the value is n^2, because each of the machines that you hook up gets to talk to all of the other machines on the network. When you graph that, you see that over time your costs go down while the value of the network goes up."[4] Metcalfe's original diagram (Figure 1) suggests that the aggregate value of compatibly communicating devices grows at a rate of square the number of units. The rise in network system costs are linear, while the value creation is exponential. So, at a key juncture—the "critical mass crossover"—value surpasses costs and continues to explode.[5]

Figure 1
The Systematic Value of Compatibly Communicating Devices



Source: *Clock of the Long Now*, Brand, Stewart.

Metcalfe's value formula can be stated more precisely as $V = n^2 - n$. For example, a network of three people has a theoretical value of six *(9 - 3 = 6)*. This "law" also tallies the potential number of transactions that can occur in a network.[6] A supplemental member adds prospective new goods, providing direct benefits to all other network members.

In the case of a network of ten people, each person has nine other potential resources. The total value of the network is 90. Assuming the number of people in the network doubles, the value quadruples, to 380 ($20^2 – 20 = 380$). If the network expands to 10 times its base size—100 people—the value swells 100 times. When the bases reaches 1,000 times the number of people, the value rises a million times.

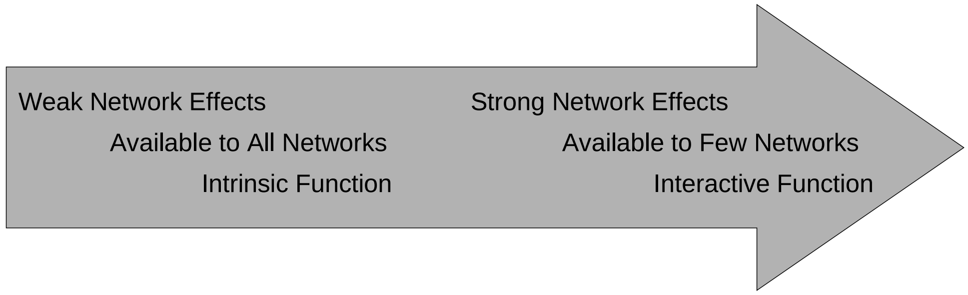
Metcalfe's Law may not be an exact mathematical expression, but it sheds light on an important idea. Economists, using more formal language, call this idea a *network effect*. Network effects exist when the value of a good increases because the number of people using the good increases. In a typical network, the addition of a new customer increases the willingness of all participants to pay for network services. This is a defining feature of networks.[7] As investors, we are interested in situations where network effects exist and can be "internalized," or captured, by the network "owners" or standard bearers. This value capture, in turn, is reflected in financial measures like sales and earnings growth.[8]

There are two major types of network effects: direct and indirect. Direct network effects exist when the value of a good changes as more agents consume *that good*. For example, the value of eBay's network grows as more users join, as buyers are provided with more choices and sellers are able to set higher prices. Indirect network effects arise when the value of a good increases as the number, or variety, of *complementary* products expands. For instance, the success of a computer operating system is not solely dependent on its technological advantages, but also on how much complementary software is available in the market.[9] And your DVD player becomes more valuable as more movies are released on DVD.

Network effects not only come in different types. They also come in different levels of *intensity*. As investors, we are particularly interested in situations where networks effects are both powerful *and* can be captured as shareholder value. We address the issue of value creation in the following section. For now, we want to answer the fundamental question: How do you know when network effects are significant?

Think of a traditional airline's hub-and-spoke network. As long as it effectively takes you where you want to go, you probably don't honestly care if other passengers use the same service. But networks effects do exist, because the addition of more passengers allows the airline to expand routes and provide all users with added services. In some cases, however, the network effects are relatively weak. Yahoo! users checking news updates, getting stock quotes, or finding weather information care little whether or not other users do the same. For them, the product value flows from its intrinsic usefulness. However, these same customers are much more concerned with the value of the network if they put something up for auction or join in on a message board discussion.

Figure 2
Network Effects Continuum



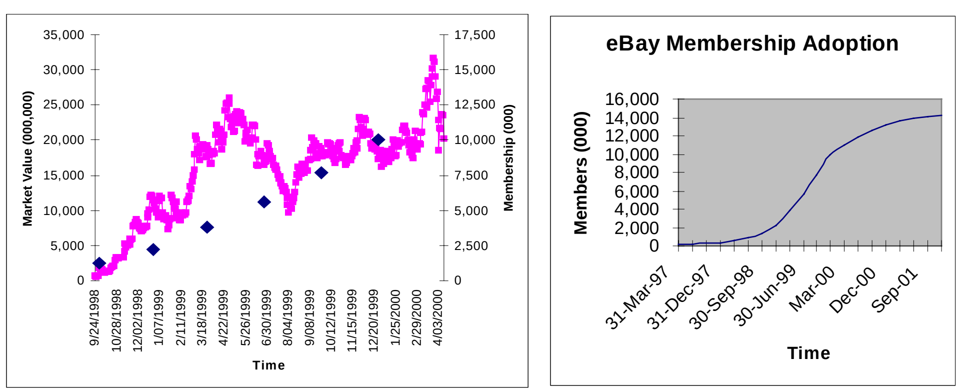
Source: CSFB analysis.

We have identified what we believe are the three strongest forms of network effects. All of them hinge on two drivers: *interactivity* and *compatibility*. Interactivity means that there is a lot of contact among the members, or nodes. Such interactivity allows individuals to impart value to the network. The more contact, the stronger the potential network effects. Compatibility comes in a few forms: transactions, community, and devices. We address each of them in turn:

- *Transactions.* A network based on transaction compatibility derives its value by creating a forum for exchange. As more and more participants flock to the forum to conduct business, network value grows. And if the exchange captures the majority of the buyers and sellers in a particular space, competing exchanges can never reach critical mass.

  A good example is eBay, the world's largest online trading community. eBay was the first to attain scale in the auction space. Not surprisingly, its attractive growth and economic performance lured two other Internet heavyweights, Yahoo! and Amazon.com, into the fray. But neither Yahoo!'s huge installed base and free listings nor Amazon.com's experienced e-commerce users proved enough to unseat eBay as the overwhelming market leader. Notably, eBay's success came despite little proprietary technology. The key was volume of users.

Figure 3
eBay



Source: Company published data, CSFB analysis.

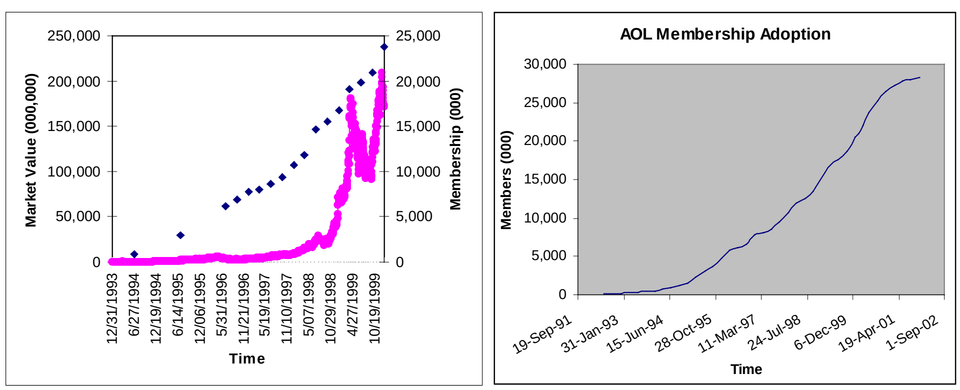
In less than two years, eBay has grown from less than 1 million to a staggering 12.6 million registered users. This exponential growth is shown in the right panel of Figure 3. In mid-1998, the company hit a point on the curve when user growth took off.[10] Users want to be where everyone else is. Sellers seek liquidity and the highest selling prices. Buyers seek the greatest depth and breadth of assorted goods. So it's easy to see how eBay internalized these network properties to the benefit of their shareholders. The diagram on the left in Figure 3 shows eBay's market value relative to its growth in registered users. The registered user data almost look like a trend line through the market-value data.

However, it's not always so easy from an investor's perspective. The market is a discounting mechanism. So it's not important when the firm actually reaches critical mass. Rather, it's important when the market *thinks* the firm will reach critical mass. At that point, the market creates a tectonic shift in value creation, enriching the shareholders that had the foresight to jump on the wave.

- *Community.* In networks with direct interaction between members, value grows as more participants join the community. And once a community has gathered, content providers, advertisers, and vendors are willing to pay for access to that community.

  America Online isn't typically thought of as an online community. But over the last five years, it has managed to become an integral part of the U.S. communications network. In 1996, AOL naysayers insisted that a closed online service with proprietary content would eventually collapse because of the Internet's free and open nature. The rise of cheap Internet service providers and widespread offering of free e-mail promised a swift end for America Online. But rather than fold, AOL thrived. Some of its appeal stemmed from its organized content—as opposed to the scary, messy Web—and ease of use. But that wasn't the whole story. AOL also facilitated communication among friends, family, and other members with similar interests. Stories proliferated about adults graduating from the Internet's "training wheels" only to find that their children had grown impossibly attached to America Online's message boards, chat, and instant messaging.[11]

Figure 4
America Online



Source: Company published data, CSFB analysis.

Interestingly, studies have shown that computer adoption is not associated with any kind of particular software but is highly correlated with the use of e-mail and the Internet. Computers are part of the local information and *communications* network.[12] Once America Online penetrated a sufficient number of users, further adoption almost became inevitable, facilitated by friends and family. This effect is seen in Figure 4, which plots America Online's membership growth with its growth in market capitalization.[13]

- *Devices.* In addition to the merits of direct compatibility, the value of a device is often a function of ancillary devices, services, and software. For example, the value of your VCR is in large part contingent on the number of videocassette tapes that you can play on it. Lots of tapes, lots of value. No tapes, no value. As a device becomes more available, it spawns co-evolution of ancillary devices, services, and software, which in turn spurs even further growth for the device. Eventually, the device becomes a de facto standard (anyone still got a Betamax lying around?) providing the producer with the potential for massive value creation.

  Operating system software is a good example. When you buy a new operating system, your decision is likely based on the intrinsic value of the software package: features, speed, and compatibility with other products. Arrayed against this are the purchase cost, transition headaches, and incompatibility issues. But ultimately, an operating system can't grow without compatible software applications.[14] And the greater the availability and growth of compatible applications, the higher the value of the operating system, and vice versa.

  Microsoft's operating system dominance began with a cost advantage over Macintosh. The Macintosh graphical user interface required more computing power than DOS, and hence the Mac was more expensive. Further, DOS was faster than Macintosh, and many businesses were only using computers for one application. These factors—combined with small hard drives and limited interaction with the operating system—meant that the Mac's few advantages over DOS were outweighed by disadvantages.[15] The result: leading application software companies of the day, including Lotus 1-2-3, Ashton-Tate, and WordPerfect, poured resources into developing DOS-based products. More compatible products, more value.

  Eventually, Microsoft unveiled its own graphical-user-interface-based product, Windows. But it did so only after microprocessors became faster, hard drives larger, and memory cheaper. Microsoft also made Windows backward-compatible so it wouldn't strand its existing user base. The value of Microsoft's network of Windows users really took off when users quickly transitioned from DOS to Windows. By then, the market share battle had been won. DOS's early cost advantage was amplified by the wave of application software written for it. The positive feedback loop then kicked in. Microsoft became the focal point of the PC software value chain, and it reaped extraordinary returns as a result.

We have now established the significance of network effects, and have outlined where they tend to be most powerful. Now we turn to the next subject: the economics of networks.

Networks and Economic Value

A company's ability to create shareholder value is fundamentally derived from its ability to generate a return on invested capital in excess of its cost of capital for as long as possible. Excess returns can be expressed as the difference between revenues and costs, while duration of excess returns can be articulated as sustainable competitive advantage. In this section, we explore the ways networks generate revenues, their cost dynamics, and how they sustain competitive advantage. Analysis of these drivers provides us with a foundation for understanding the valuations afforded successful networks as well as how extraordinary wealth is created in very short time periods.

We have found that there are two dimensions of sales to consider: the source and the rate of growth. Both are important, but the rate of growth is particularly interesting because it is *nonlinear* when strong network effects exist. And the stock market tends to be poor at accurately discounting nonlinear growth. Therein lies opportunity.

But first, we deal with the revenue sources. Here, we outline five major categories of sales. Many established networks gather sales from more than one of the categories. In some instances, there are revenue opportunities that developed networks have yet to exploit. So these categories are meant to serve not only as a means to classify sales, but also as a way to think about potential value creation. The categories are as follows:

- *Commerce/transactions.* Companies that are a de facto standard or stewards of a network can either sell goods directly or can steer customers to a transaction and collect a fee (indirect). Direct sales are conceptually straightforward and generally easy to track. The success of a company's indirect sales relates to its ability to reduce customer *search costs*. Large networks that can effectively direct users are very valuable.

- *Advertising.* Large user networks are very attractive to advertisers because the users can be reached cost-effectively. Companies that have amassed such groups can monetize them by selling advertising. Since an advertising-based business model is typically only viable for companies with a sizable user base, companies trying to build such a model often discount or give away their product in order to corral users. The giveaway is a costly means to a profitable end: becoming an attractive vehicle for advertisers.

- *Subscription.* Some successful networks can charge users a subscription fee, or dues, for access to a network and its content. Subscription models usually apply for one of two extremes: very specialized networks or very large networks.

- *Data.* One of the benefits—and concerns—of the digital age is an unprecedented ability to collect information. Companies with large user bases, especially ones that are Internet-based, have a treasure chest of data about their customers that is valuable because it can be sold to third parties. These data can be either aggregated, hence skirting privacy issues, or used to offer specific consumer profiles.

- *Incubation.* Once a network is established, it can "link and leverage" its position into new business opportunities. An example is a model that is increasingly ubiquitous on the Internet, where a company with a strong network simultaneously buys an equity stake in another company and promotes it to the network (often for a fee). The network bearer can then win in two ways—with fee income and a potential equity upside.

Now that we have outlined revenue sources, we can turn back to the issue of growth rates. To do that, we must introduce and explore the notion of positive feedback. Positive feedback is the idea that the strong get stronger, which necessarily includes the corollary—the weak get weaker.

Positive feedback has been around for a long time. For example, as a manufacturing company increases its size, it often benefits from economies of scale. That is, as a company gets bigger, it lowers its average unit cost and improves its economic returns. But for those companies—and even for some networks where network effects are muted—the positive feedback is *supply-side* driven. It is based on a company's manufacturing or processing capabilities. Eventually, the positive feedback dissipates because of size, bureaucracy, or complexity. And this generally happens well before a company reaches market dominance.

For networks, the primary source of positive feedback is network effects. And rather than being supply-side driven, network effects are *demand-side* driven. This difference has two immediate and critical implications. The first is that once a network passes critical mass (the subject of the next section), users *want* to join the network, and will do so at the expense of competing networks. This desire leads to a surge in demand—or nonlinear growth. The second implication is that for networks based on intellectual property, market share is *not* governed by size. One network can, and often does, become totally dominant, garnering market shares unthinkable in the physical world. Natural monopolies are the progeny of strong network effects.

Noted economist Brian Arthur says it more bluntly in what he has dubbed Arthur's Law: "Of networks there shall be few." In a particular space, one network tends to dominate, while the rest fight over the scraps. Network builders understand that anything other than first place is an also-ran.

We now turn our attention to the nature of costs. There are two fundamental ways to "scale" a business—that is, to grow sales at a faster rate than costs. The first is to employ physical capital more efficiently. This tactic involves good old-fashioned economies of scale. The second is growing a business that has low incremental, or variable, costs. High up-front and low incremental costs are a hallmark of information goods. Think of a piece of software. It takes a huge amount of human capital to write the code the first time. But once finished, the cost of replicating and distributing that code is often very low.

So when network effects and the cost characteristics of information goods are introduced to one another, the result is potentially explosive. A surge in demand-side driven sales, coupled with negligible incremental cost, leads to significant value creation. This is why some new economy networks have been able to garner multibillion dollar valuations so quickly.

That is the good news. The bad news is that the up-front cost of developing a network in an information-oriented domain is typically very significant. And if multiple competitors see the same pot of gold at the end of the rainbow, they will all spend heavily to acquire users, knowing there is seldom an economic prize for the runner-up.

A network business's asset mix, then, heavily influences how it scales. Networks based on physical assets tend to have moderate fixed costs and moderate variable costs.[16] Networks based on information assets tend to have high up-front costs and low variable costs. Figure 5 includes a theoretical model that illustrates the sizable margin impact. For a physical business with a 30% fixed/70% variable cost structure (company B), doubling output leads to a rough doubling in operating margins. For an information business with a 90% fixed/10% variable cost structure (company D), margins rise fourfold as output doubles.

In considering the potential scalability of a business model, it is important to separate economies of scale from the concept of high up-front/low incremental investments. For example, some startups show scalability early on, but the source of this advantage is vitally important. Although both sources of scalability benefit from network effects, the trigger for reinvestment (i.e., additional costs) is different for each. In a physical network, capacity constraints trigger reinvestment. At a certain point, the network needs more infrastructure to support its growth.

For an information-based network, reinvestment is triggered by obsolescence. These networks must keep their products or services up-to-date, or risk losing users to a more technologically advanced offering. But the key is that *while an information-based product or service is current, sales and costs become uncoupled.*

Figure 5
Scale Economy Effects

Cost Structure 10% fixed / 90% variable	**Company A**		
Output (units)	1,000,000	1,250,000	2,000,000
Revenue ($1.25 per unit of output)	$1,120,000	$1,400,000	$2,240,000
Fixed	$100,000	$100,000	$100,000
Variable ($0.90 per unit)	$900,000	$1,125,000	$1,800,000
Total	$1,000,000	$1,225,000	$1,900,000
Margin	10.7%	12.5%	15.2%
Cost Structure 30% fixed / 70% variable	**Company B**		
Output (units)	1,000,000	1,250,000	2,000,000
Revenue ($1.25 per unit of output)	$1,120,000	$1,400,000	$2,240,000
Fixed	$300,000	$300,000	$300,000
Variable ($0.70 per unit)	$700,000	$875,000	$1,400,000
Total	$1,000,000	$1,175,000	$1,700,000
Margin	10.7%	16.1%	24.1%
Cost Structure 70% fixed / 30% variable	**Company C**		
Output (units)	1,000,000	1,250,000	2,000,000
Revenue ($1.25 per unit of output)	$1,120,000	$1,400,000	$2,240,000
Fixed	$700,000	$700,000	$700,000
Variable ($0.30 per unit)	$300,000	$375,000	$600,000
Total	$1,000,000	$1,075,000	$1,300,000
Margin	10.7%	23.2%	42.0%
Cost Structure 90% fixed / 10% variable	**Company D**		
Output	1,000,000	1,250,000	2,000,000
Revenue ($1.25 per unit of output)	$1,120,000	$1,400,000	$2,240,000
Fixed	$900,000	$900,000	$900,000
Variable ($0.10 per unit)	$100,000	$125,000	$200,000
Total	$1,000,000	$1,025,000	$1,100,000
Margin	10.7%	26.8%	50.9%

Source: CSFB analysis.

All of the stock market tumult and business model upheaval in today's world begs a central question: Where is the competitive advantage in a rapidly shifting economy? We believe that networks are one of the few sources of sustainable competitive advantage.

Once entrenched, dominant networks prove difficult to dislodge. The game is theirs to lose. Switching costs are a prime variable in appreciating a network's sustainable competitive advantage. A switching cost is the cost a user bears when he or she switches from one system to another. These costs fall into two categories. The first is the cost associated with learning a new system. The second is the cost of losing interaction with other users.

Consider the daunting decision facing the first customer pondering a switch to a new network. Even if the new network is inherently better, no network effects arise with a single user. So the switching cost is huge for that individual. Even if a sufficient number of people *are* willing to switch to a "superior" network, it is not likely to happen because coordination is so difficult. In fact, collective switching costs are far higher than all individual switching costs because of the coordination hurdle.

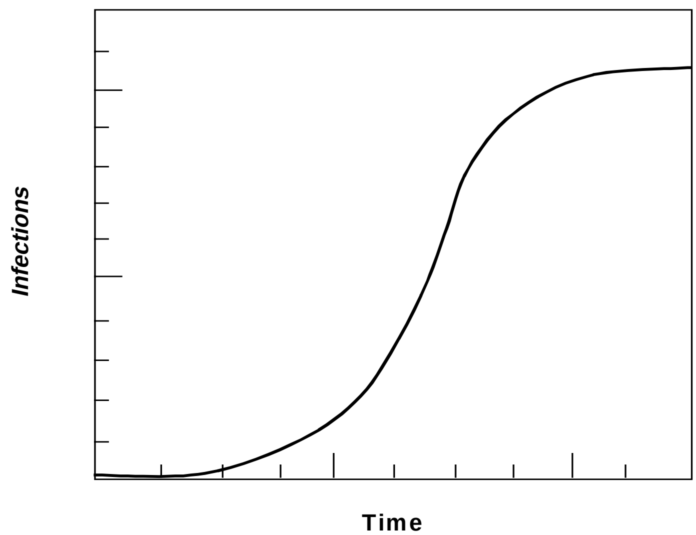
When evaluating a network of users, one has to consider the switching costs on a per customer basis and aggregate those costs. Small switching costs for a huge user base can be equivalent to large switching costs for a single user, even though the latter is much easier to appreciate. Most companies benefiting from network effects understand this point, and work hard to increase "stickiness."

Network Formation—Time to Get Critical

First, we investigated network effects and identified when they are particularly pronounced. We then looked at how networks generate economic value, noting that information-based networks have potentially explosive economics. We now turn to the final question: How do networks form?[17] And perhaps the even more pressing question for investors: Is it possible to determine which network will win?

If you want to understand network formation, you can start by thinking about the flu. Actually, we're really interested in how the flu *spreads*. There are two key dimensions, both intuitive. The first is the degree of interaction—that is, how often people run into one another. The second is the degree of contagiousness—how easily it spreads. If there is a lot of interaction, but the flu strand is not particularly contagious, it will not take off. If the flu is very contagious but its carriers don't interact with others, it will not take off. But combine contagiousness with interaction, and you've got an epidemic.

Figure 6
Disease Propagation

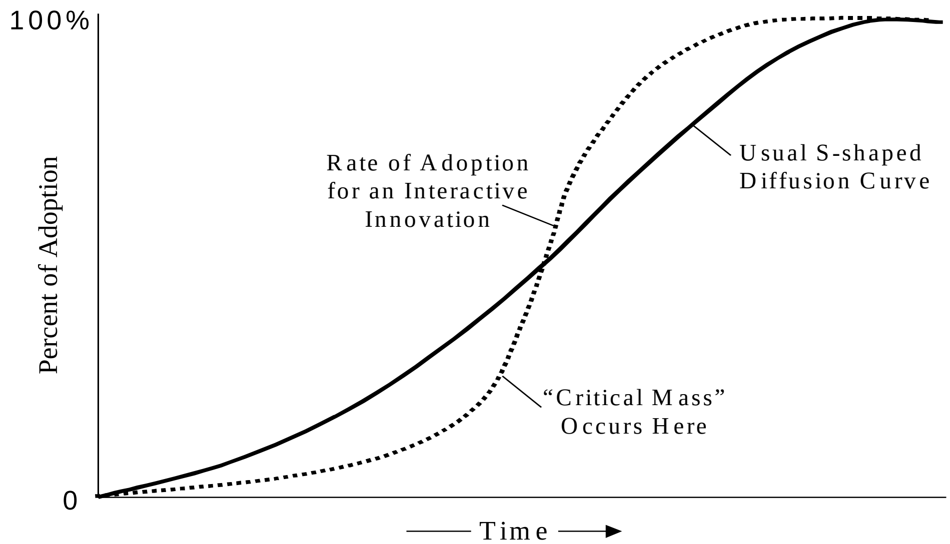


Source: Newman, M.E. J. and Watts, D. J., *Scaling and Percolation in Small-World Networks.*

As it turns out, the spread of innovations and the spread of diseases look the same when graphed. They both follow an S-curve. That is, adoption starts off slowly and increases at an accelerating rate once the innovation (disease) takes hold. Not surprisingly, our biological analogy points to business-world parallels. The degree of interaction can be thoughtfully modeled as the "small world" effect. And susceptibility, or contagiousness, can be understood as adoption thresholds. We will delve into these concepts in a moment.

Before we do that, we need to draw out another important distinction—the difference between the diffusion of "noninteractive" and "interactive" innovations. A noninteractive innovation is perceived to be increasingly beneficial to future adopters as more and more individuals adopt. So, it follows an S-curve. With interactive innovations (including most networks with strong network effects), not only do earlier adopters influence later adopters, but *later adopters also influence earlier adopters*. So the benefits from each additional adoption flow to *all* existing and future users. As a result, an interactive innovation follows a much steeper S-curve (see Figure 7).

Figure 7
Rate of Adoption



Source: Everett M. Rogers, *Diffusion of Innovations*.

We all know that only some innovations succeed. So what's the key to rapid adoption? The answer is that the good or service has to get to critical mass. The metaphor comes from physics. Critical mass is the key to detonating an atom bomb. When the unstable nucleus of uranium breaks up, energy is released. Neutrons emanating from the breakup of one may hit another and cause it to break up, but most neutrons miss other nuclei and are projected harmlessly into space. If, however, the quantity of uranium is appropriately condensed—critical mass—the typical neutron leaving one nucleus will hit another, and so on, causing a self-sustaining chain reaction.

Similarly, an innovation is said to reach critical mass when it begins to increase at an accelerating rate. Even if active promotion of the innovation is disrupted, the process continues. The innovation is self-sustaining.[18] And it becomes nearly impossible for competitors—or even the company's own management miscues—to change the course. The authors of the *Gorilla Game*, a superb book on high-technology investing, offer a simple rule of thumb for when a company has gotten to critical mass: "when year-to-year growth approaches or exceeds 100%, and when quarter-to-quarter growth is also rapidly accelerating."[19]

Why do people adopt an innovation? Individuals don't adopt an innovation solely based on its intrinsic benefits. People are also influenced by what other people do. But not all adopters are equivalent in their potential to be influenced. Individuals have what's called an *adoption threshold*. An adoption threshold is defined by how many other people must engage in an activity before a given individual joins in as well. In innovation diffusion, a threshold is reached when an individual adopts the technology because enough other people have already done so.

Interestingly, individual adoption is more heavily influenced by adoption in a user's personal communication network than by aggregate adoption. This means that the structure of communication networks is all-important when assessing how the diffusion process works for interactive innovations. An innovation spreads much quicker over a network that has an average of six degrees of separation than one that has sixty. The structure of social networks has been formally explored in the literature on the *small-world effect*.

One of the central ideas in the small-world literature is called *clustering*. Clustering is the degree to which the connections to one node also connect to one another. For example, in your friendship network, it's the degree to which your friends are likely to know each other. Not surprisingly, many real-world networks are highly clustered.

When modeling these networks, researchers discovered something fascinating: Just a few, random, long-range connections between local, clustered networks dramatically reduced the path link—the degrees of separation. A social analogy would be a tightly knit group of friends living in New York City, with a member still in contact with friends in Los Angeles. Just a few random links, and the overall degree of separation plummets.

So what does this have to do with network formation? The tremendous potential value of a network is *not* a function of how many people have adopted it. Rather, *a network's potential comes from how many nonadopters are in the social cluster of the adopters.* The true power of the network effect lies in the adoption cascade through the various social clusters. Given the degree of interconnectedness afforded by the Internet, the small-world effect suggests that network formation should be more rapid than ever.

In fact, it is.[20] Less than six months after its launch, Hotmail, a free e-mail service, registered its one-millionth user. And less than 18 months later, the subscriber number shot up to over 12 million people. Another case in point is Napster, which provides software that allows its users to automatically search and download MP3 files from other users. It has built a network of 9 million members in a span of just 6 months.[21]

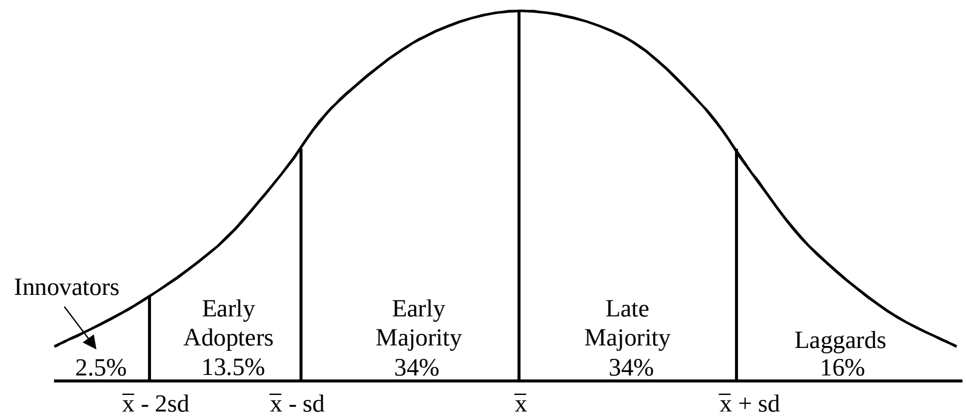
We now summarize three key points:

- Interactive innovations, including networks, grow at a faster rate than noninteractive ones.
- An individual's adoption threshold is defined by how many other people in his or her social cluster engage in an activity before they join in as well.
- The small-world effect shows us how communications technology makes us more connected to one another than ever before.

So far, our discussion has focused largely on the architecture of network formation. We will now review the *process* of formation. And for that, we turn to the dean of diffusion, Everett Rogers. Rogers first published his oeuvre, *The Diffusion of Innovation*, in 1962. It remains a classic today.

The familiar S-curve represents *cumulative* adopters of an innovation. Rogers found that the plot of new adopters tends to be a normal distribution. (See Figure 8.) This finding allowed him to categorize adopters based on how early they are willing to adopt an innovation relative to other members of a social system. Rogers broke adopters into five groups based on statistical measures.[22] Fans of technology strategist and•ber author Geoff Moore—especially his books *Crossing the Chasm* and *Inside the Tornado*—will find the graphic and nomenclature familiar. Crossing the chasm means getting to critical mass.[23]

Figure 8
Adopter Categorization



Source: Everett M. Rogers, *Diffusion of Innovations.*

The process starts with *innovators* and *early adopters*. Innovators are a group obsessed with "venturesomeness." They are known for their technological savvy, and are willing to cope with the distinct possibility that the innovation will never be adopted in the mainstream. The innovators are the gatekeepers of new ideas.

Early adopters are more integrated with society than innovators, and are often opinion leaders. Since early adopters are often asked for advice, they understand that they must make judicious innovation decisions.

In an attempt to get to critical mass, the *early majority* is the crucial group. The distance between the early adopters and the early majority is the chasm that has to be crossed. The psychological profile of the early majority fits the old saying, "Be not the first by which the new is tried, nor the last to lay the old aside."[24] Consequently, they tend to be cautious before completely embracing a new idea. But they are a large group and provide a key ingredient that an innovation needs—legitimacy.

Interactive networks encourage adoption by providing the early-majority incentives that a regular network cannot supply. Once an interactive network has taken root, strong network effects provide benefits that fit neatly with the needs of later adopters, thus accelerating overall adoption rates. In contrast to the innovators and early adopters, the early majority can clearly see the benefit of network effects and factor them into the decision-making process. Transaction networks have more liquidity, device markets more complementary products, and community networks more members with which to interact. Interactivity becomes a substantial input in the value calculus above and beyond the intrinsic product merit.

Exhaustive studies of innovation diffusion show that the point of critical mass is typically between 5% and 20% penetration of the total market served. Beyond this point, increased adoption becomes self-sustaining. Moore calls this period of growth "the tornado."

Critical mass can also be viewed as the "tipping point."[25] When two or more firms compete for a market where there is strong feedback, one typically emerges as the winner. The point of no return, where one company's success begets further success, is called the tipping point.[26]

A simple example makes the point. Say two new restaurants open next door to one another in your neighborhood. The food, ambiance, and prices are comparable. You decide to go out to dinner with your friends. Which restaurant would you pick? Provided you are really indifferent with regard to the offerings, you might pick one restaurant at random and try it out.

Now imagine another group of diners arrive just a few moments later. Which restaurant are they likely to choose? Well, they probably look in the window, see *some* people eating at one restaurant, while the other is empty. Chances are you'll have company. And all of the groups that follow will be influenced by your random choice. Positive feedback made one restaurant a winner—at least for a night.

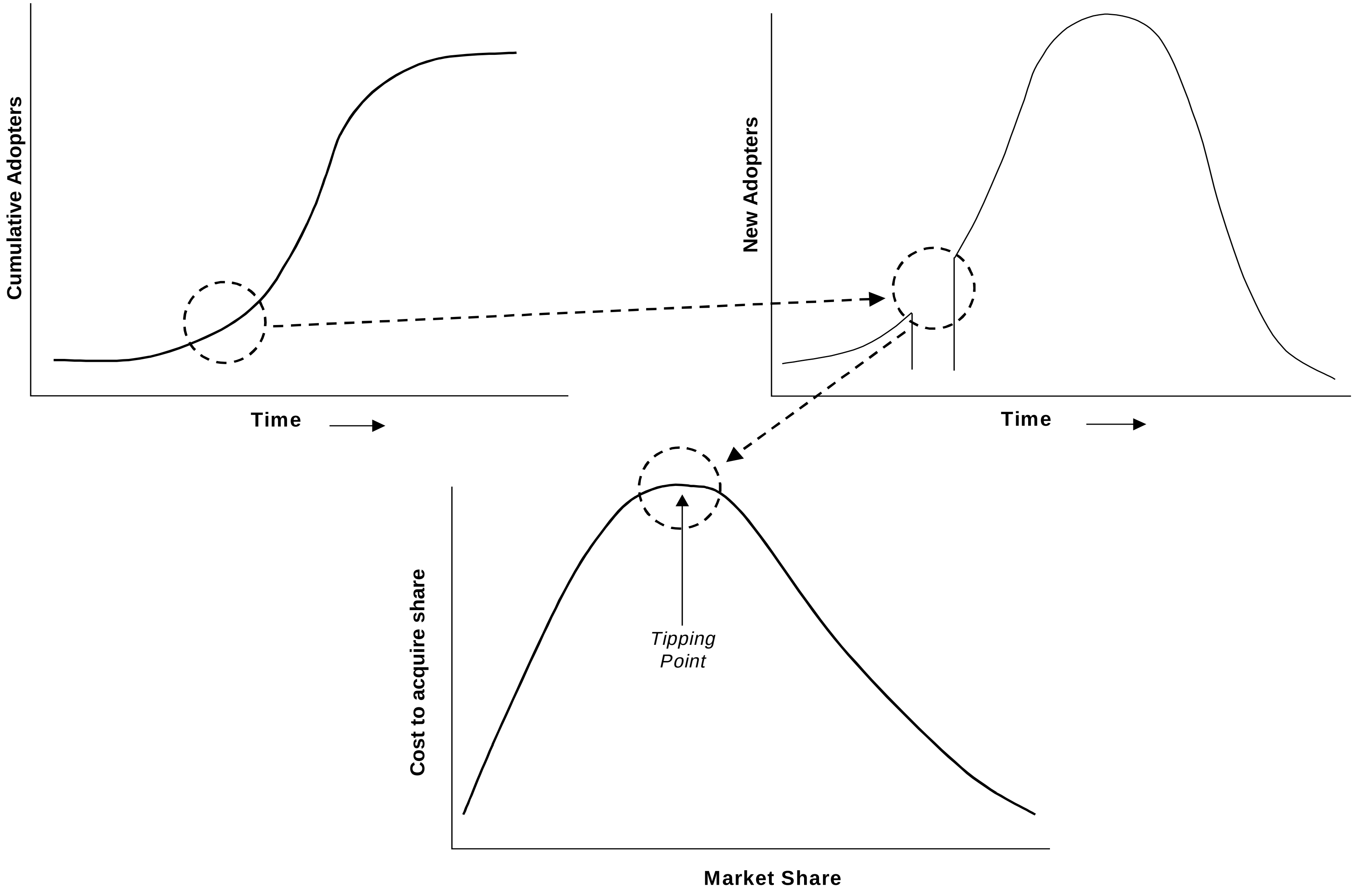
The real message in the tipping point is an economic one. Typically, one or more companies will vie to become the network of choice. Early market-share gains are both challenging and expensive. But if by skill, foresight, or luck one company gets a lead in a "tippy" market, positive feedback is likely to carry it to the tipping point, or to the point of critical mass. From there, it is shareholder value nirvana: market share rises precisely as the cost of gaining that market share declines.[27]

Figure 9 provides a complete map of critical mass. Critical mass can be described in three ways:

- The inflection point—or elbow—in an S-curve.
- The transition from the early adopters to the early majority— or "crossing the chasm."
- The tipping point, where incremental market share comes at incrementally lower costs.

While our discussion has largely dwelled on the mechanics of network formation, we cannot lose sight of the fact that most networks never get to critical mass. Equally important to stress, however, is that a network or innovation that is intrinsically valuable won't necessarily win in the marketplace. *A great offering is a necessary, but not sufficient, condition for getting to critical mass.*

Figure 9
Getting to Critical Mass



Source: Everett M. Rogers, *Diffusion of Innovations*, Geoffrey A. Moore, *Crossing the Chasm*, and Jeffrey Williams, *Renewable Advantage*.

Conclusion

Networks have been around for a long time. But they are becoming a much more significant part of the economic landscape for two primary reasons. First, the precipitous drop in communication costs—including the tsunami called the Internet—means that people are more connected than ever. As a result, networks can form more frequently, and at a faster rate, than ever before. Second, the global economy is rapidly changing from one based on physical assets to one based on intellectual assets. This shift has fundamentally and irrevocably altered traditional links between sales and costs.

The stakes in the network game are high. Network effects played a prime role in Microsoft's ability to create $350 billion in market value over the past 15 years. And eBay, not even five years old, commands a $20 billion market capitalization because of the extraordinary virtual transaction market it has built.

Yet this is not a phenomenon confined to the new economy. The eruption of business-to-business exchanges, many of which serve old-economy companies, is proof positive.[28] These exchanges will profoundly transform the way business is conducted in the future.[29] Traditional companies increasingly understand this truism, and are insisting on equity stakes in the new networks in return for their sponsorship and participation.

It is our view that all business decision-makers—including managers and investors—should become intimate with the ins-and-outs of networks.

But there is no panacea here. The balance of evidence suggests that many network opportunities amount to winner-take-all. Even for those that win, the size of the addressable market can limit their fortunes. And the creative gale of disruptive technology is omnipresent.

Figure 10
Summary Chart

	Initial Advantage	*Value Measured By*	*Sustainability*	
Communication	Best perceived source of information and valuable interactions with other members. Trialability.	• Membership dues • Advertising • Partnerships	• Quality content • Observability • Buzz	• Best information and; • Minimize complexity • Reinvention
Exchange	Buyers get fair prices and best selection, while sellers get liquidity and the benefits of highest price from a large market of buyers. Trialability.	• Transaction fees • Membership dues • Advertising • Partnerships	• Relative advantage • Compatability • Complexity • Trialability	• Observability • Buzz • Reinvention
Devices	A superior solution is offered that is non complex and not a radical departure with the past.	• Product purchase • License fees • Service Fees	• Relative advantage • Compatability • Complexity	• Trialability • Observability • Buzz • Reinvention
Resource				

Source: CSFB analysis.

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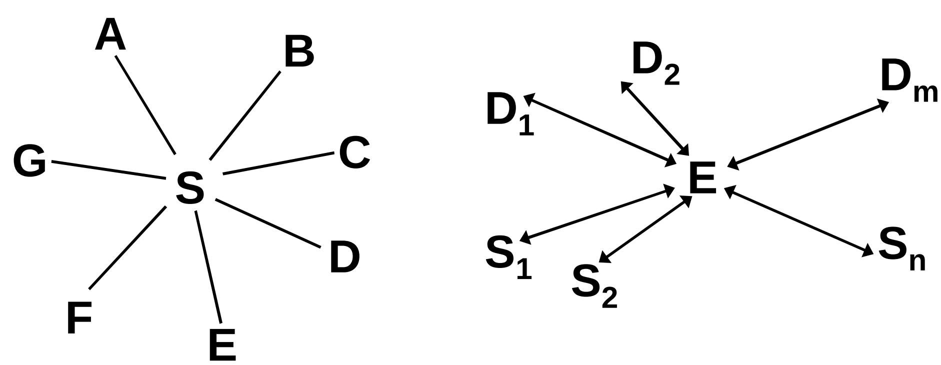
Appendix A

Complements

Networks can be distinguished by whether or not all the components on the network are complementary to each other. Networks where only some components are complementary to each other are dubbed “one-way” networks. Networks where all the components are complementary are called “two-way” networks. Network effects arise because there is complementarity between the components of the network. Formally, networks are composed of links that connect nodes. Two basic network structures are shown in Figure 11. The figure on the left is a simple star network where peripheral nodes (A,B,C, etc.) orbit the central node S. On the right is a financial intermediation network where representatives on the demand side ($D_1D_2D_m$) and supply side ($S_1S_2S_n$) meet at exchange E.

Figure 11
Network Classification



Source: Economides, Nicholas, *Network Economics with Application to Finance*.”

Assuming the star network on the left is a basic telecommunication network, a phone call from A to B is composed of AS and SB, where S is the switching service. Though AS and BS look very similar, they are in fact complements and not substitutes. Since AB and BA are distinct goods—the call originating from A and received at B versus the call originating at B and received at A—the network is called a two-way network. Traditional two-way networks include railroad, road, and many types of telecommunication networks.

In the financial intermediation network, agents on the demand side and supply side want to engage in a “trade,” matching their offer with another offer. In this way, an offer to buy D_1E is complementary with a matching offer to sell S_1E, but by definition it is not complementary with any other offers to buy or sell. In this setup, ASB, BSA, and ASC are all composite goods made up of complementary components. In a one-way network, customers are not identified with individual components, but instead demand composite goods. Since, D_1E S_1 is identical to good S_1E D_1 (as opposed to the telecommunications network, where AB and BA are distinct goods), the configuration is a one-way network. In addition to most financial exchanges, other traditional one-way networks include paging and broadcast networks.

It is important to note that the topology of the network doesn’t determine whether a network is one-way or two-way. The star network on the left could just as easily be a paging network, where A pages E through radio tower S. Since ESA is not feasible except as a separate good, the network is determined to be one-way.

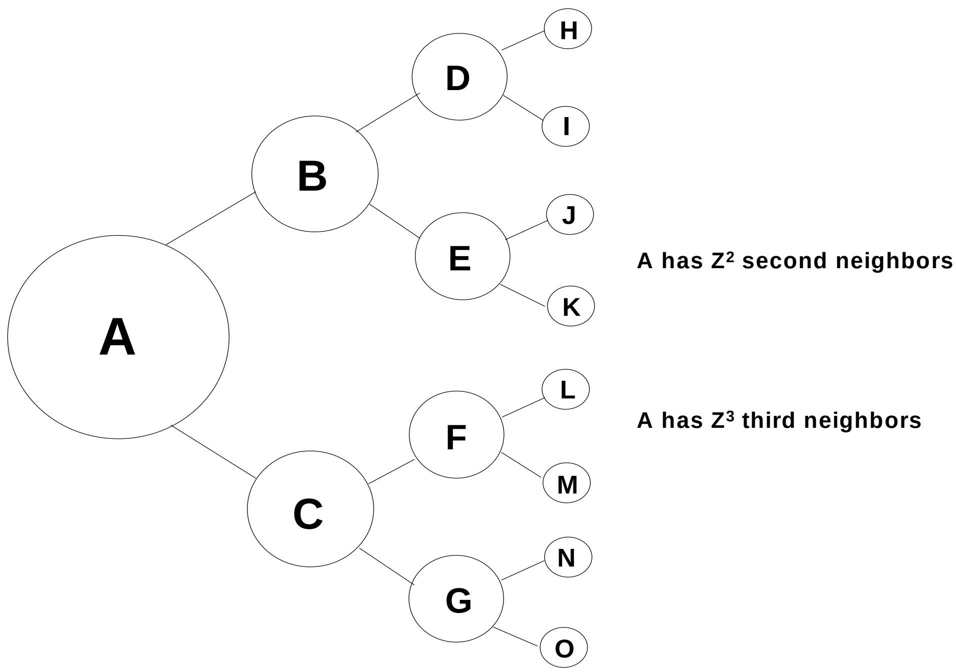
Even though the star and financial intermediation network configurations seem very different, all networked goods benefit from network effects. The addition of a new node in the network positively affects the complementary components. Adding one more node in an n-node network creates 2n new products. In a financial intermediation network where a new offer to buy or sell will ultimately be matched with only one counterparty, the number of potential transactions increases by 2n as well (assuming everyone in the network can take either side of the transaction at any given time).

Appendix B

Six Degrees of Separation

Historically, the mathematics of the small-world effect was explained with completely random graphs.[30] Assuming a certain number of people in the world (N), and an average number of acquaintances (z), means that there are $^1/_2$Nz connections between people in the whole population. The number represented by z is called the coordination number, but here we call it the acquaintance number.

Figure 12
Random Graph

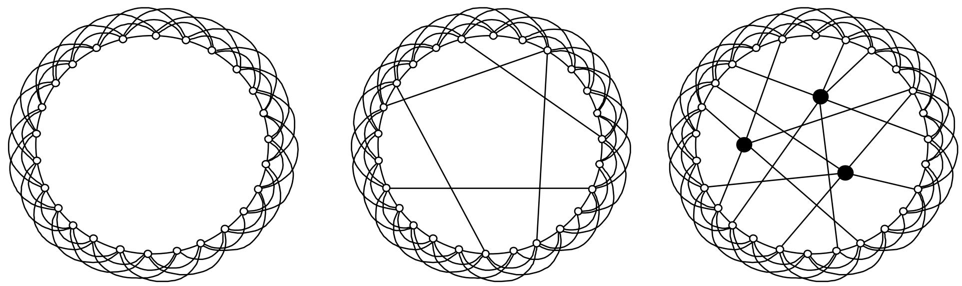


Source: CSFB analysis.

If we were to make a chart and connect all the people in a network together with lines ($^1/_2$Nz) drawn between randomly chosen pairs, the result would be a random graph. If the coordination number is two, then a typical person (A) would have two acquaintances. These two acquaintances would, in turn, have two other acquaintances. The result is a situation where A would have z^2 (4) second neighbors and z^3 (8) third neighbors (as seen in Figure 12). The diameter (d) of the network, or the total degrees of separation among users of the network, is a function of the increase in the total people that join the network. In a completely random graph, the degrees of separation will only increase logarithmically as the total population grows. Thus, the number of degrees of separation can be quite small even in a very large or growing network.

While this random graph does describe a small world, it has a number of problems that hinder its use as a model for real-world social networks. Taking the above example, it is not really true to say that A has z^2 or four neighbors that are two degrees removed. In most social networks, the probability that the two friends of my friend are also acquaintances of mine is usually high. This condition is called *clustering,* and it is ubiquitous in social networks.

Figure 13
Networks



Source: M. E. J. Newman, *Small Worlds: The Structure of Social Networks*.

A regular network is depicted on the left-hand side of Figure 13. It is highly clustered in that each node, or person, is connected not only to his or her immediate neighbor but also to each neighbor's neighbors. However, this configuration represents a "large" world. As the number of nodes on the network grow, the average degrees of separation begin to grow linearly as well. Contrast this with the completely random network, where the average degrees of separation increase much more slowly as the number of nodes increase. Since random networks still need to confront the clustering issue, the solution comes in the form of a regular network, with some links randomly "rewired."

This outcome is depicted in the center of Figure 13, where each of the links on the lattice is assigned a probability that it will be rewired, meaning that one of its ends will be moved to a new position. For a low probability of rewiring, the resulting graph is still very regular, but a number of connections are spread a long distance across the lattice. To use a social analogy, think of a tightly knit group of friends living in New York City, with one of the members maintaining contact with friends in California. Even with a tiny amount of random links, the overall degrees of separation between nodes are remarkably similar to a fully random network. The small-world phenomenon is a generic feature for many large, sparse networks. In essence, it only takes a few shortcuts to reduce the size of the world.

Figure 14
Empirical Examples of Small-World Networks

Network	N = nodes	l = avg separation	l = random separation	C = clustering	C = random
Movie Actors	225,226	3.65	2.99	0.79	0.00027
Neural Network	282	2.65	2.25	0.28	0.05
Power Grid	4941	18.7	12.4	0.08	0.0005

Source: Strogatz, Steven H.; Watts, Duncan J., *Collective Dynamics of 'Small-World Networks.*

Far from being just a mathematical ideal, the three real networks in Figure 14 nonetheless exhibit small-world effects. When clustering is taken into account, the average degrees of separation between nodes do not vary substantially with a completely random network containing the same amount of nodes. Since the value of l in these networks is quite low when compared with the number of nodes, there is clearly a small-world effect at work.

In addition to the explanation that the small-world phenomenon arises from a couple of long-range connections in an otherwise short-range social network, other theories have emerged. The author Malcolm Gladwell has proposed an alternate small-world model, as depicted to the far right of Figure 13. Under this model, a few nodes in the network have unusually high coordination numbers.

That is, there exists a certain “type” of person in a social network that is able to foster acquaintance relationships with a widely distributed set of neighbors. This so-called “law of the few” also accounts for the small-world effect.

[1] Gilder, George, "Law of the Telecosm," *Forbes*, June 1, 1998.

[2] www.intel.com/intel/museum/25anniv/hof/moore.htm.[2]

[3] Metcalfe has stated on numerous occasion, with tongue firmly planted in cheek, that he is more than willing to take credit for the law even though he wasn't the first to come up with the concept.

[4] From an interview in *Red Herring* magazine, November 1994.

[5] If costs were truly n and value n^2, then the diagram could actually never show the cost curve above the value curve, hence $V \bullet n^2$. A more clear relationship would show the critical mass crossover of two lines y=x^2 and y=ax +b with the y-axis representing value and the x-axis representing the number of nodes in the network. Metcalfe's original diagram was taken from Brand, Stewart*, The Clock of the Long Now: Time and Responsibility: The Ideas Behind the World's Slowest Computer*, Basic Books, New York, 2000.

[6] In our three-person network (let's call the members A, B, and C), A can transact with B or C, B can transact with A or C, and C can transact with A or B, summing to six.

[7] Economides, Nicholas, "Network Economics with Application to Finance," *Financial Markets, Institutions & Instruments*, vol. 2, no. 5, December 1993, pp. 89-97.

[8] When network effects were first discussed in the economics literature, they were widely called "network externalities." However, network effects and network externalities are not necessarily the same thing. An economic externality occurs only when a decision-maker does not confront, or bear, the full costs or benefits of an action. In the most popular example of an externality, automobile pollution, car users confront many of the costs associated with the use of an automobile (gas, oil, wear and tear, insurance rates, and even highway repairs through the tax on gasoline), but not all of them. As car owners drive along, they pollute the air with fumes and noise, and slow down other drivers. Because these costs are largely borne by other drivers that do not confront the offending driver with remunerative demands at the end of the day, they are called negative externalities. An externality does not have to be negative. A simple example of a positive externality is when someone takes the time to spruce up his or her yard. In so doing, he or she also benefits the neighbor's view without receiving any form of compensation. Notably, for some networks, the benefits of adding additional users can be "internalized," or captured by the "owners" and users of the network. In this case, the network is said to exhibit network effects, but without an externality.

[9] In a typical one-way network, network effects are primarily indirect. When there are m varieties of component A and n varieties of component B (all *A-type* goods are compatible with all *B-type*), there are mn potential composite goods. An extra customer yields indirect network effects by increasing the demand for components of type A and B, potentially increasing the number of varieties of each component as well.

[10] The top of the curve was determined by assuming that eBay will no longer grow. If it does indeed grow, then the curve will ultimately look steeper, consistent with an interactive innovation.

[11] Swisher, Kara, *aol.com*, Random House, New York, 1998.

[12] Goolsbee, Austan, "Evidence on Learning and Network Externalities in the Diffusion of Home Computers," University of Chicago, July 1999.

[13] Another more direct example of the value of a community-based network is the price paid to acquire it. Numerous deals were inked in 1998 and early 1999 merging various digital networks of interacting members. Yahoo! purchased Geocities with its 19 million users, Lycos acquired the 1 million members of Tripod for $58 million, and Go2Net snatched up 100,000 individual investors of the Silicon Investor network for $33 million.

[14] Aside from direct compatibility.

[15] Liebowitz, Stanley J.; Margolis Stephen E., *Winners, Losers & Microsoft : Competition and Antitrust in High Technology*, Independent Inst., California, 1999 Although the authors argue that Microsoft's success came solely from the intrinsic merits of its offering and not network effects, we disagree. Compatible device network effects have a strong influence on the early majority.

[16] A variable cost is a cost that increases as output increases. For example, a commission paid to salespeople for their production would be a variable cost. A fixed cost is a cost that remains constant even as output increases. The property taxes due on a company's facilities are an example. Utilizing the language of fixed and variable costs, a basic model can be constructed to highlight the effects of cost structure on the margins of a growing business.

[17] Many frameworks have been devised to assess the ability of an innovation to get to critical mass. Most can be classified along the following qualitative dimensions:[31]

Relative advantage—The degree to which the innovation is perceived to be better than what came before it.

Compatibility—The degree to which the innovation is perceived to operate within the framework of the prior values of users.

Complexity—The degree to which users perceive the innovation to be complicated.

Trialability—The degree to which an innovation can be used on a trial basis, without full commitment and without complete disruption to what it replaces.

Observability—The degree to which others can readily perceive the use of the innovation and mimic adoption.

Reinvention—The degree to which the innovation can change and adapt as it diffuses to meet the unanticipated needs of users.

This framework comes courtesy of Everett Rogers.

[18] It's important to note that critical mass does not refer to the cumulative amount of people that have adopted, but to the number of nonadopters that these agents of change actually influence.

[19] *Gorilla Game*, p. 211.

[20] Jeff Bezos stated that before the Internet, growth like this had only been seen in a petri dish.

[21] "Can Napster be Stopped? No!" Bill Gurley, *Fortune*, April 17 2000.

[22] The innovativeness variable is partitioned into five adopter categories by laying off standard deviations from the average time of adoption.

[23] Moore's forthcoming book, *Living on the Fault Line: Managing for Shareholder Value in the Age of the Internet,* is terrific and highly recommended.

[24] This line comes from *An Essay on Criticism* by Alexander Pope, and was used by Everett Rogers to characterize the early majority of adopters

[25] Malcolm Gladwell's *The Tipping Point* is dedicated to the concept.

[26] In Amazon.com's 1999 annual report, CEO Jeff Bezos writes, "We believe we have reached a 'tipping point,' where this platform allows us to launch new e-commerce businesses faster, with a higher quality customer experience, a lower incremental cost, a higher chance of success, and a clearer path to scale and profitability than perhaps any other company."

[27] It's important to note that not all markets tip, and not all network products witness an inevitable adoption cycle due to tipping.

[28] For a good summary, see "Online Supply Networks Boom, But Some Major Hurdles Loom" by Clare Ansberry, *Wall Street Journal*, April 17, 2000.

[29] These exchanges create value through two different mechanisms, aggregation and matching. Aggregation brings a large number of buyers and sellers together under one roof, reducing transaction costs through the provision of "one-stop shopping." The matching mechanism brings buyers and sellers together to negotiate prices on a real-time basis. Under the aggregation mechanism, adding another buyer to the hub only benefits sellers, for there is no swapping of roles. This is unlike the matching mechanism, where it is possible that buyers are also sellers. The matching mechanism benefits from stronger network effects, by improving the overall transaction value. Kaplan, Steven; Sawhney, Mohanbir, "E-Hubs: The New B2B Marketplaces," *Harvard Business Review*, May-June 2000.

[30] The history of the development of small-world effect is beautifully summarized in Newman, M. E. J., "Small Worlds: The Structure of Social Networks," Santa Fe Institute, 1999.

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GENEVA.................41 22 394 70 00	PASADENA 1 626 395 5100	WARSAW................ 48 22 695 0050
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