Economic sense of Metcalfe's Law

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ABSTRACT

Metcalfe's Law was widely accepted and used to explain internet boom. It has drawn a lot of criticism in explaining Web 2.0. This paper connects Transaction Cost Theory (TCT) with Metcalfe's Law. It not only proves that they are consistent but also makes economical sense of the Law by introducing the second critical mass in to Metcalfe's Law. Efforts are also used to explain exiting Web effect and future of Web evolutions. It concludes that any format of the future Web evolution has to have cost reduction in its core.

Categories and Subject Descriptors

F.2.1 [**Numerical Algorithms and Problems**]: *Computation of transforms*

General Terms

Algorithms, Economics, Theory, Verification.

Keywords

Transaction cost theory (TCT), Metcalfe's Law, Theory, Models, WEB 2.0, Web evolution, Web effect, Social effect, Web Future.

1. INTRODUCTION

In talking about the future of Web, there are many different opinions [1, 6, 13]. Web 2.0, Semantic Web, Grid, Web service, Mobile Web, Ubiquitous and Pervasive Computing are just a few of a long list. How to explain these diverse opinions? Are we going to experience a second round web blooming lead by web 2.0 or are we inflating a second Internet Bubble and lead to an imminent Bubble busting? To answer these questions, a unique model is needed. This model has to be capable of explaining Web's past and the future of Web evolution.

Up to date the most cited and widely accepted model, which can explain the "web effect" in the past, is Metcalfe's law. It is named after Bob Metcalfe, the inventor of the Ethernet and founder of 3Com, Circa 1980 by his colleague George Gilder [4]. Metcalfe's law states "*the value of a telecommunications network is proportional to the square of the number of users of the system (n^2).*" The basic point of Metcalfe's Law is that the value of networks exhibits super-linear growth. Clearly this law encourages the connections for a simple reason that is to achieve enormous value. It also explains many of the network effects of communication technologies and networks such as the Internet, social networking, and the Semantic Web [5].

However there are people who don't agree with Metcalfe's law. Some people argue that the Metcalfe's law over estimates the values of networks and inflated the Internet Bubble in the past and is trying to inflate a second Internet Bubble through web 2.0. Therefore it is not only wrong but dangerous [2]. Other people accused that Metcalfe's law failed to explain the social effect and the phenomena of the web 2.0 all together, therefore is irrelevant [10]. This paper, from an economic point of view, argues that it is not only relevant but also consistent with a well established and widely accepted economical view. That is Transaction Cost Theory. Attempts also made to explain existing phenomena of the Web and its future evolutions. Section 2 describes the original transcription of the Metcalfe's Law and its recent extension. Section 3 provides Transaction Cost Theory and its implications of structural change among business organisations. In section 4, a connection between Metcalfe's Law and TCT has been made and consistency between them is drawn. Inspired by TCT, the second critical mass has been introduced into the Metcalfe's Law. Section 5 provides author's view on value, which is the vague point of Metcalfe's law. Section 6 explains the existing and future trend of the Web using Metcalfe's Law. Final section is the conclusion.

2. METCALFE'S LAW

The original Metcalfe's Law was trying to explain the reason why customers needed Ethernet cards to grow above a certain critical mass if they were to reap the benefits of their network (see Figure 1).

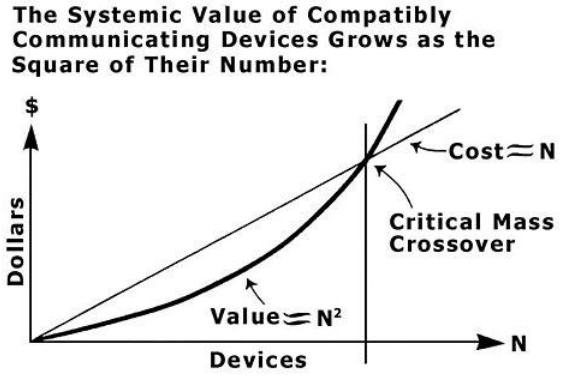

Figure 1. The original transcription.

According to Metcalfe [8, 9], the rationale behind the sale of networking cards was that,

(1) the cost of cards was proportional to the number of cards installed, but

(2) the value of the network was proportional to the square of the number of compatibly communicating devices. This was expressed algebraically as having a cost of "N", and a value of "N^2".

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This increase in value as the network grows inspired the entrepreneurs, venture capitalists and engineers during the internet boom. They all believed that the Law has offered a quantitative explanation for the many mantras such as "network effects", "internet time" and "build it and they will come".

Clearly the growth cannot go on forever. That is to say trees never reach sky. There are other implied points. Point 3 is added by Metcalfe on VC Mike's web Blog [16].

(3) A critical mass after which the benefits of a network grow larger than its costs. The number of users at which this critical mass can be calculated by solving C*N=A*N^2, where C is the cost per connection and A is the value per connection. The N at which critical mass is achieved is N=C/A. It is not much of a surprise that the lower the cost per connection, C, the lower the critical mass number of users, N; and the higher the value per connection, A, the lower the critical mass number of users, N.

(4) The value of a network can not always grow. It may actually starts going down after some size. If C*N=A*N^2, it could be that C and A are also functions of N and heads down after some network size, N', the second critical mass, overwhelming N'^2. This A is called "affinity", the value of per connection. Also N'=C/A. It is the same rule that the lower the cost of per connection, C, the lower of a second critical mass N'; and the higher of affinity, the lower the second critical mass N'. There two key points in here. One is that both cost C and affinity A are functions of N. it means that some connections are cost or value more others. The other point is that N'>N.

3. TRANSACTION COST THEORY (TCT)

The Nobel Prize winner Ronald Coase set out his Transaction Cost Theory (TCT) of the firm in 1937, making it one of the first attempts to define the firm theoretically in relation to the market [3]. At its core is this notion: When a company tries to determine whether to outsource or to produce goods or services on its own, market prices are not the sole factor. There are also significant transaction costs, search costs, contracting costs and coordination costs. Those costs frequently determine whether a company uses internal or external resources for products or services. This is the essence of the "make" versus "buy" decision. The core unit of analysis in TCT is the transaction, which "*occurs when a good or service is transferred across a technologically separate interface*" [14]. Transactions costs arise for ex ante reasons (drafting, negotiating, and safeguarding agreements between the parties to a transaction) and ex post reasons (haggling, establishment, operational, and bonding costs). Decision makers must weigh up the production and transaction costs associated with executing a transaction within their firms (insourcing) versus the production and transaction costs associated with executing the transaction with other firms (outsourcing). If they choose outsourcing, they must then determine the appropriate form or type of governance structure to use.

Williamson [15] argues that two human and three environmental factors lead to transactions costs arising. The two human factors are:

1. Bounded rationality: Humans are unlikely to have the abilities or resources to consider every state-contingent outcome associated with a transaction that might arise.
2. Opportunism: Humans will act to further their own self-interests.

The three environmental factors are:

1. Uncertainty: Uncertainty exacerbates the problems that arise because of bounded rationality and opportunism.
2. Small numbers trading: If only a small number of players exist in a market place, a party to a transaction may have difficulty disciplining the other parties to the transaction via the possibility of withdrawal and use of alternative players in the marketplace.
3. Asset specificity: The value of an asset may be attached to a particular transaction that it supports. The party who has invested in the asset will incur a loss if the party who has not invested withdraws from the transaction. The possibility (threat) of this party acting opportunistically leads to the so-called "hold-up" problem.

Williamson argues that three dimensions of a transaction affect the type of governance structure chosen for the transaction: asset specificity, uncertainty, and frequency. As asset specificity and uncertainty increase, the risk of opportunism increases. Thus, decision makers are more likely to choose a hierarchical (or tight integration) governance structure. As asset specificity decrease, the higher transaction frequency tends to be, therefore the loss control is desirable since the market form is likely available.

Table 1. A summary of the relationship between asset specificity, uncertainty and governance structure.

		Asset specificity	
		Low	High
Uncertainty	High	Contract/vertical integration	Vertical integration /hierarchical
	Low	Spot contract /market	Long-term contract

Table 1 summarizes the relationship between asset specificity, uncertainty and governance structure. There is no frequency in the table. This is because frequency associates with asset specificity. Generally, high specificity links the lower volume and the lower frequency of transactions; low specificity associates with high volume and frequency of transactions. Therefore, Market has character of low uncertainty, high transaction volume, and frequent transaction and low asset specificity. On the contrast, hierarchical structure is associated with high asset specificity, high uncertainty, low volume and low frequency of transactions.

It is interesting that the "Bounded rationality" and "opportunism" lead to a so called "flocking" or "herding" behavior, which is when one person moves, other will follow, even if it is not a good idea. This can explain the "recommendation" phenomena.

4. CONSISTENCY BETWEEN METCALFE'S LAW AND TCT

Metcalfe's law states that value of a system created by the connections exhibits super-linear growth. It points to a critical mass of connectivity after which the benefits of a network grow larger than its costs. It also indicates that the value of a system will not grow indefinitely. Once the size of a system grows to a certain point, that the cost of connection outweights the value or benefit of the connection, a disconnection may occur. This is precisely the transaction cost theory. Business starts from producing a product or providing a service. Its very existence

shows that it somehow has a niche. In other words it is very special. The specificity is high, and also the transaction volume and frequency is low. Once it has been massively produced and has huge volume of transactions. Its market value, which to its consumer is the cost of obtaining or loss it, will be low. As consequences of these, plus human "bounded rationality" and "opportunism", the established hierarchical structure will give ways to free market. In other words, it means the end of the hierarchical structure replaced by a free market. Its existing consumers are free to shopping around.

The second consistency is revealed in the explanation of "web effect" and "social effect". TCT points out that due to massive reduction of transaction cost according to Moore's law for example, the governance structure of organisations will move towards free market, where high volume and high frequency transaction will be observed. TCT also tells that in a free market-place, there "Flocking" behaviour exhibited by the customers because of the "bounded rational" and "opportunism". Metcalfe's Law states, the cost of the computing and communication used to create connectivity is halved every two years according to the Moore's Law. Combining Moore's and Metcalfe's Laws together, the number of users at which a network's value exceeds its cost halves every two years. In the same time, the value of connectivity has been going up. For example, In the 1980s Ethernet connectivity allowed users only to share printers, share disks, and exchange emails. But today, Internet connectivity brings users the World Wide Web, Amazon, eBay, Google, iTunes, blogs and social networking. The Internet's value per connection, A, is a lot higher now, which means the both critical mass sizes N and N' are much lower now because of C/A. It means connections created, become profitable and disbanded much faster. Why wonder flocking phenomena?

The third consistency between Metcalfe's Law and TCT is that they both fallen in a category of "rule of thumb". Although Metcalfe's Law attempts to quantify increase in values as the network grows. To apply hard mathematics to sociology is difficult if not impossible. Metcalfe himself admitted that Metcalfe's Law is a vision thing not a precise mathematics. Regarding the value of connections, Metcalfe's Law has a notion of "affinity", which is the value of per connection. The Law admits that connection is not same as communication. It means that some connection does not necessarily result in meaningful communication. Affinity A is not a constant. It changes in different connections. The value depends on who evaluate it and how to value it. In TCT, realising the difficulties of evaluating transaction cost, Williamson does not provide a definite list of parameters for consideration and nor a unique scale system to value a parameter. They are both principles in a quantified manner.

5. THE VALUE THING

Perhaps the most vague point of the Metcalfe's law is the notion of the "Value". When talking about value, there are three issues around: 1) what value? 2) Who's value? and 3) how to value?

5.1 What Value?

People accept the difference between what Metcalfe said and how the Law is remembered. It is to do with how the size of the network is measured, which means devices versus users. They are different in a sense that connecting devices and machines may exhibit a good scale but this is not true when connecting users. On one hand, humans get overloaded with information fairly quickly so that you cannot connect huge number of users and expect they are useful to process information flow on the network. This is where the "affinity" is meaningful. On the other hand, perhaps rather strange, humans tend to value large user systems more than large connection of devices. This is perhaps where the advertise-driven web business can find its theoretic root. It is clear that the web is not only capable of connecting machines but also capable of connecting users. The later is more interesting and it is later the social effect occurs. Between connecting machines (Ethernet) and connecting users (Facebook), web also connects documents (html), connects contents (Semantic web), connects services (SOA) and even connects abilities (Grid). Therefore not machine nor user is a unique determinant. The size of a network and the value of network are similar as the cost and the benefit of a transaction, it is a perception of interesting party. Any parameter choice has to do with the context of the problem. For example, with a web network, we need to consider not just the number of users but also the affinity between the members of the network. Each network connection we make carries an intangible, personal quality that has direct impact on how much we value those networks and thus how much they are worth as a whole. We tot up our own value in terms like trust, engagement, joy, relevance, excitement, reputation, need and even money.

5.2 Who's value?

There is an argument that Metcalfe's Law looks at the wrong end. The value of a network is not created or evaluated at the center in terms of who owns it. But the network is valued from edge, the end user. And the end users value the networks they choose to connect to in ways only they can measure. It is clearly that the users, the owner of a network value a network differently. Many social networks such as yahoo, AOL, MSN hold a value proposition similarly like this: a) the more users, the higher value because they can ask for a higher advertise fee since its larger number users. That is why they can afford some methods attracting new users to sign up such as free in the first three months. b) As existing users, they generally under value them because they know it would cost users too much hassle to switch off their existing email addresses and other facilities. Clearly this is owners value proposition.

As for end users, we each value a network positively on what it brings us. That is different for each of us and each of our connections. For example, I see very little value, personally, of LinkedIn and other friend finder websites. Apart from attracting some spam, inconvenience, and embarrassment, it hardly provides any benefit to me. But for others, these websites provide jobs, business, income, reputation, even love and marriage. How can you price this? I also see little value in MySpace. Signing up for it is merely a curiosity. For others, like my son, it gets them songs or friends. I see value in my smart phone because it keeps me connected to anything, anywhere, anytime. I see great value in having a blog in WordPress.com, for it brings me information, knowledge and satisfaction.

5.3 How to Value?

TCT provides an economical view of fundamental rule in the economics world. Reducing transactions cost encourages transactions occurring. However it leaves questions, like what dimensions needed for consideration and how to define the cost, open in a practical life. This does not hinder any usage of the theory. On the contrary, it encourages more meaningful and precise measurements being used in any particular instances.

Malone etc. [7] in proving a trend that traditional hierarchical governance gives way to market, he uses determinants such as "asset specificity" and "complexity of product description" and measurements such as degree of business process being electronic and networked. His work provides a theoretical support for business re-organisation in 90's. A. Sutcliffe and G. Li [12] measuring cost of software from off-shelf to produced it in-house to define a model for system requirements engineering. From forms of hard cash, there are many other measurements of value. E-commerce can be easily measured by turn over or profits. Many social connections are measured by participants' satisfaction. The only measure which is unique is that a personal perception on cost over the benefits that one can have.

6. WEB 2.0 AND FUTURE EXPLANATION

In this section some existing Social networks and future Web evolution are explained using Metcalfe's Law.

6.1 "Niche"-"Critical Mass"-"split"

Most of exiting web 2.0 networks starts from a market niche. Users find it is useful, or influenced by others, or simply sign up for it because of human "bounded rationality" and "opportunism". Or after a serious evaluation of the cost of signing up in terms of cost in money, time and anything else outweight the expected benefit in money, time or stratification. Each new user does have the ability of adding value (both for users and the net work owner). Then the network continues to grow before reaching the first critical mass. Then the benefit and value of connection grow faster than before. Then the second critical mass has been reached. The connection starts to struggle and eventually disbanded. A new cycle starts. The critical mass depends on individual users and the usage of the networks. For example, Alumni websites for an individual user, the second critical mass is actually very small. The maximum will be the total number of the school classmates. For other networks and users the number could be much larger. For example, flickr has to get thousands of users before it becomes a good place to search for pictures. That is the first critical mass. Once the second critical mass is reached, the additional value offered by more users may not be as great as it was. When the value added by new users is less than the cost of maintenance of the connections (either by user's view, i.e. one cannot find one's friends; or by owner's view, i.e. advertising profit is less than the cost of customer service), then the network will split or branch. Another cycle of Web life is starting. During this process some grow bigger and others fade away.

QQ, MSN, and **Skype** are IM service providers. QQ dominates the Chinese market and had a staggering 580 million users at the end of the 2006 and it grows continuously. According to China Internet Network Information Center (CNNIC), Chinese online population has grown by 23.4% in 2006 vs. 18.1% for 2005. Broadband user growth is at an even higher rate of 41.1%, reaching 91M. Country internet penetration rate is 10.5%, versus mobile phone penetration of 40%. There is still much room to grow as we know the overall population in China. The user number grows in line with Metcalfe's Law. This is a typical advertising-driven web site. It is clear that the more people in the network add more value for the network owner and the value comes from what they contribute via ad clicks. As for individual users, it depends on your usage. If you use it for communicate with your friends, the value will be great once your friends are on; If you are seeking new friends with similar interests to you, then the chances of finding someone are far higher if there are many users; If you only want to talk to your existing social group, then the other thousands of users are an irrelevance to you.

Digg, with many other similar news or blog web sites, are places for people to discover and share news, image and video content from anywhere on the web. It also holds "the more people add more value". If there were only a dozen people it would not be any useful of news. Each additional user adds much value to it up. The extra users will find and submit more stories from more far-flung corners of the internet. The extra users also have wider views on an issue. Larger numbers of people voting or tagging means that the promoted stories that get to the front page will be more representative of what the larger population finds relevant and interesting. However there will be a point that there is more interesting news than you can read. Then you may ignore it all (the second critical mass has been reached).

MySpace, similar with other social networks such as **Facebook**, is a place where people share information. Again it holds the proposition of "more is better". Ideally, you would like to connect with all your friends. However if they are not on MySpace then it will be no use for you. Once your friends are on, then the value of the network is enormous. However, if the extra user has no any common interest with you in any sense, then their added value to you may be negative.

Flickr and **YouTube** are primarily photo and video sharing networks. Their business niche is visual and young age users. The value of more users depends entirely on how you use it. If you use it to share photos and videos with your friends, then all you really care about is that your friends are able to connect to the site. It does not matter at all if there are 20 users or 20 million. On the other hand, if you are using it to find photos on a particular topic or to look at pictures, then the more the better.

6.2 Connect (machine, document, information, contents, service, ability) – reduce transaction cost

Tim Berners-Lee has summarized the web evolution with a track which starts off connecting computers (through wires), to connecting documents (through WWW); then to connecting contents (through semantics Web, DAML.OWL); then to connecting the ***Thing*** (that semantically trying to communicate) [1]. It is an interesting view of this progressive evolution. Continuing the track, the future of the Web may be connecting people. That is "Social Web". In a similar manner with internet phenomena, which people can forget about individual connections between computers and only interest in *Messages* went from one computer to another; also similar with Web phenomena, which people can forget protocols and only interest in the *Documents*, the social web phenomena will let users forget machines, wires, protocols, ontology, location, and any other facilities, the only thing users are interested in is the ***Thing***. This ***Thing*** will be there, anywhere at any time. In order for this to happen, many people have proposed different futures of Web from different viewpoints [6, 13]. These include Web of trust, Semantic Web, Mobile Web, Web services Grid and Pervasive Computing. They are all valid views in an unprecedented and complex environment.

To model these complicated and diverse activities is hard. However, to some extent it is a similar challenge faced by sociologists and economists while to define "*business firm*" and the activities of "*doing business*". Thankfully, TCT, simplifies all kinds of interactions between technically different interfaces as

Transaction. Using TCT to model human "*flocking*" behavior since the "bounded rationality" and "opportunism"; and "firm" as business organization unit; and Transaction Cost (cost/benefit ratio) to define inter-organizational relationship: market vs. hierarchy. Hierarchical structure is normally represented by "vertical integration", "buy off", "sign very restricted and long term contracts", etc. It can be regarded as "*becoming a single firm if they were not*". Market, on the contrary, usually represented by "loose coupled", "randomly connected", or even "buy when needed". It can be regarded as "*no relationship*". Moving from a hierarchical relationship to market means changing from intend to buy a company to having no relationship with it. The conditions are, product or service has very low specificity, the environment has high certainty; there are huge volumes available and transaction occurs very frequently. Is this sounding familiar? Yes. That is what I said earlier, "*it will be there, anywhere at any time.*" In order for this to happen, TCT tells us that the cost of transaction will be low, low and low. The transaction in here is any interaction across different interfaces.

In my opinion, all the efforts on Semantic Web is trying reduce the cost of connecting contents; efforts on trust and security management is trying to reduce the cost of negotiation and coordination; efforts on Grid is to reduce the cost of sharing facilities and abilities; efforts on ubiquitous and pervasive computing is to reduce cost of access any resources. It is simple, isn't it? How many times we have lost in the past? In order to make things simple we have introduced dozens more complicated things, schemas, standards, languages, processes and so forth. It is nothing wrong with them. It is wrong to expose this to users. Remember that it is user who makes decision how much cost. Therefore the efforts should be on letting users forget schemas, standards, languages, processes and so forth and only focused on the ***Thing*** interested to them.

7. CONCLUSION

This paper is an effort in seeking theoretic model to guide the future of the web evolution. Metcalfe's Law is widely accepted and used model to explain to Web evolution from earlier internet bloom to web 2.0. It attracts much investment on the field because it states that the value of connections exhibits super-linear growth. After dot-com bubble, many people critics Metcalfe's Law and accuse it as relevant when talking about future Web. This paper draws author's knowledge on TCT and connects TCT with Metclafe's Law. From economic view point, not only prove they are consistent but also re-interpret Metcalfe's Law and introduced the concept of the second critical mass in a context of explaining exiting Web effect and future of Web evolution. The author believe the success of future Web lies in reduce of transaction cost.

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