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Testing Metcalfe's law: Pitfalls and possibilities

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ABSTRACT

A small but burgeoning body of literature has tried to assess whether Metcalfe's law provides a realistic yardstick for the value of specific networks. In this paper, I uncover a number of flaws in the extant tests. First, a proper test of Metcalfe's law—or of any of the competing "laws"—requires correct identification of the type(s) of network effects involved and the relevant market(s). Second, a multi-market setting typically calls for scaled network sizes. Third, controlling for intertemporal changes in network quality may be imperative. Finally, indicators at the individual and aggregate levels should not be mixed. Armed with these insights, I re-examined Madureira et al. (2013)'s results. Unlike Madureira et al., I found that Metcalfe's law fits the data better than Briscoe's law.

1. Introduction: a world of networks

With the ever-increasing digitization of production and consumption processes, a growing number of goods and services in a growing number of industries have become, or are becoming, so-called network goods; that is, goods that derive at least part of their utility from their connection to a network of sorts. While most think of social networks in this regard, physical goods also are not immune to this trend. The online platform of Dutch startup 3D Hubs, for example, connects 3D printer owners with "makers" who would like to have something printed in 3D. In summer 2016, the 3D Hubs "community" comprised some 32,000 printers in over 150 countries[1].

Given their increasing prevalence, a deeper understanding of the economic value of "networks", "communities", or "platforms" has become imperative for researchers, practitioners, and policymakers alike. Abstracting from the risk of congestion, there is little doubt that the value of a network increases as it adds members; the question is by how much. A popular heuristic is Metcalfe's law, which states that the value of a telecommunications network is proportional to the square of the number of users. As Robert Metcalfe himself pointed out, however, until recently "nobody (including me) has ever made the case for or against Metcalfe's law with real data" Metcalfe (2013). A series of recent articles have examined Metcalfe's law since then, but unfortunately all the proposed tests can be criticized in one or more respects.

This paper uses the extant literature, and especially an article by Madureira et al. (2013), as a springboard to point out a number of pitfalls for researchers who would want to examine the value of networks. Specifically, I point out that a bona fide test of Metcalfe's law requires a correct identification of the type(s) of network effects involved as well as of the boundaries of the market. I also argue that a multi-market setting typically, but not always, calls for scaling of network sizes, and that controlling for inter-country differences or for intertemporal changes in the nature of the network may be required. Finally, I assert that it is vital to take the same point of view—either that of users or network owners—for all indicators involved.

The paper proceeds as follows: In Section 2, I introduce Metcalfe's law and its alternatives, and also summarize the existing approaches, in particular the efforts of Madureira et al. In Section 3, I raise five questions concerning the tests. In Section 4, I build on the answers to these questions to amend the approach of Madureira et al. and re-examine a selection of their results. In Section 5, I present my conclusions.

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[1] Source: 3D Hubs, 3D Printing Trends, July 2016 https://www.3dhubs.com/trends (last accessed 29.08.16).

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2. Existing tests of Metcalfe's law

As mentioned, the most popular rule of thumb for the value of a network is Metcalfe's "law", which focuses on the number of possible connections among members. Applying this logic, and assuming incompatibility with other networks, the individual utility of belonging to a network with n members would be proportional to $n-1$. The aggregate value of the network—that is, number of members *times* individual utility—would then be proportional to $n(n-1)$, or roughly to n^2.

Critics argue that Metcalfe's law is overoptimistic (Metcalfe, 2013). Especially Briscoe et al. (2006) take issue with Metcalfe's assumption that all connections are equally important[2], and consider Zipf's law, which assumes decreasing marginal utility, to be more realistic. Therefore, they propose that the value of a network of size n grows in proportion to $n\log(n)$, or $n\ln(n)$ in Madureira et al.'s (2013) notations. Madureira et al. call this "Briscoe's law", and view it as an extension that would hold for large networks, rather than as an alternative to Metcalfe's law. Metcalfe (2013) calls it "Odlyzko's law".

Briscoe et al. do not support their claim with data from real networks. In fact, Metcalfe himself and Madureira et al. developed the first empirical tests of Metcalfe's law only recently, and independently from one another. Metcalfe's article also triggered two follow-up papers.

Metcalfe's own test is very simple: he takes the annual revenues of Facebook as a surrogate for the value of its network, plots data for the period 2004–2013 in a graph, programs the Metcalfe's law function in Python (with a slider attached to the proportionality factor), and, after adjusting the slider, obtains "a pretty good visual fit" (2013, p. 30). However, Metcalfe has no point of comparison, as he does not attempt to fit Briscoe's law. Another problem is that, as Metcalfe acknowledges himself, "Facebook creates much more value than is captured and monetized by Facebook selling ads" (ibid.)[3].

Conversely, Madureira et al. (2013) do not attempt to directly measure the value of the Digital Information Networks (DINs) they study, but rather try to circumvent the problem by focusing on the use that is made of the networks. Specifically, they rely on the Holonic Framework (HF) developed by Madureira et al. (2011). This framework consists of 13 "capabilities" that enterprises or individuals can use to derive utility from accessing digital information. One such capability is "selectibility", defined as the "capability of a node/user in a network to scan or search for the unknown or [to] generate courses of action that improve on known alternatives" (Madureira et al., 2013, p. 248). Madureira et al. operationalize nine of these capabilities with Eurostat data on IT usage in 33 European countries. Selectibility, for example, is proxied by the fraction of enterprises using Internet search engines (Madureira et al., 2013, p. 250). Madureira et al. also posit the following causal chain: "DINs → capabilities → economic value" (2013, p. 249). While they operationalize only the first step, they assume that enterprises or individuals use capabilities because "they have direct returns on value from that use" (Madureira et al., 2013, p. 254). Hence, they argue, the selected usage indicators y_c (with c for capability) can be seen as proxies for the "real economic value in €s" (Ibid.).

In this setup, Madureira et al. want to test whether and how usage of the capabilities—over time and across countries—correlates with the size of the relevant DIN. However, their Eurostat dataset does not provide absolute numbers of enterprises and households that have access to the Internet, only fractions. As a result, Madureira et al. cannot simply test Metcalfe's law as

$$y_c = k_{c,M} n^2, \tag{1}$$

with $k_{c,M}$ = the "coupling strength between the size of the network and the value generated by capability c" (2013, p. 247) and with the subscript M referring to Metcalfe's law. Luckily, or so Madureira et al. argue, replacing absolute by relative network size "only affects the value of the proportionality constant $k_{c,M}$" (2013, p. 248); therefore, they rewrite Eq. (1) as

$$y_c = k_{c,M} x^2, \tag{2}$$

with x = the *relative* size of the relevant network (the maximum value of which is 1).

For the left-hand side of Eq. (2), Madureira et al. succeed in matching 9 of the 13 HF capabilities with indicators in their Eurostat database. Importantly, not all of the data points that they collect in this way, for 33 European countries over the period 2002–2009, are of the country-year type. Madureira et al. also add observations at the level of economic sectors and regions within a country[4]. Depending on the capability, this gives them at least 191, and as many as 3635, observations (Madureira et al., 2013, p. 252).

Turning to Briscoe's law, Madureira et al. argue that, unlike for Metcalfe's law, they cannot replace n with x (2013, p. 248). They therefore compute n from

$$\begin{aligned} x &= n/I, \\ n &= xI, \end{aligned} \tag{3}$$

with I being "the potential maximum size of the DIN" (ibid.), and in this way obtain model (4):

$$y_c = k_{c,B} xI \ln(xI). \tag{4}$$

Madureira et al. find that, overall, both model (2) and model (4) fit the data "quite well" (2013, p. 254), with one exception. For selectibility, model (2) fails. Instead, usage behaves linearly, with a slope close to 1. However, Madureira et al. (2013, p. 253) argue that this is actually the upper part of a quadratic curve because for this capability there are no observations for small network sizes. More generally, Briscoe's law fits the strongly coupled capabilities, which include "adoptability" and "selectibility", better than Metcalfe's law does, but for the capabilities with a lower k the opposite is true. Madureira et al. refer to Briscoe et al. (2006) to conclude that "these results are in concordance with observations about the validity interval of Metcalfe's law" (2013, p. 254).

Finally, there are two new leaves on the branch of the literature started by Metcalfe (2013). Zhang et al. (2015) administer three improvements to Metcalfe's test: they examine two cases instead of just one (not only Facebook but also China's most popular social network, Tencent); they compute fit parameters and do not simply rely on a visual fit; and, most important, they compare the performance of four laws rather than limiting the analysis to just one. In particular, besides Metcalfe's and Odlyzko's laws, Zhang et al. also test Sarnoff's law, which holds that the value of a network increases linearly with the number of users, and even Reed's law, which asserts that network value scales exponentially. Zhang et al. find that Metcalfe's law fits the data best and that the fit is even better for Tencent than for Facebook. Van Hove (2016a), in turn, points out that the value of a social network may also be driven by increases in the variety and quality of the services offered; he therefore explicitly controls for such changes. Van Hove finds that Metcalfe's law now outperforms the other laws even more clearly.

[2] Briscoe et al. also proffer a theoretical argument, but this is refuted by Van Hove (2014).

[3] This would not be a problem if Facebook's "monetization ratio" were constant, but there is little doubt that Facebook has over time become more astute at capturing the value it creates.

[4] In Section 3, I argue against mixing observations in this way.