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# Direct and indirect network effects are equivalent: A comment on "Direct and Indirect Network Effects: Are They Equivalent?"[☆]

Jeffrey Church [a,*], Neil Gandal [b]

[a] Department of Economics, University of Calgary, Canada
[b] Berglas School of Economics and Department of Public Policy, Tel Aviv University, Israel

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ABSTRACT

Clements (2004) makes the following two claims: (i) unlike direct network effects, increases in the size of the market do not, in the case of indirect network effects, make standardization more likely, but (ii) indirect network effects are associated with excessive standardization. We show in Clements' framework that neither of these results are correct: standardization is more likely as the number of software firms increases and when the type of market equilibrium is unique – there are only multiple networks or only standardization – there is never excessive standardization, but there could be insufficient standardization, just as is the case with direct network effects.



## 1. Introduction

Clements (2004) suggests that there is an important difference between direct and indirect network effects. Clements finds that under direct network effects – a telephone network for example – a greater mass of consumers makes standardization more likely, but under indirect network effects – hardware/software networks – the opposite is true. The greater the size of the market, the less likely standardization. While direct networks are prone to tipping this is likely efficient, but the tendency in indirect networks is inefficient overprovision of standardization. Clements concludes that "a model of direct network effects is inadequate in analyzing a market in which network effects are in fact indirect" because of the difference in results.

Clements' results are also the exact opposite of Church and Gandal (1992) (CG). CG observe that there are two (opposing) effects on profits from a software firm opting to join an existing network and support a hardware technology: a network or demand effect (demand for hardware rises and hence software sales go up) and a competitive effect (more competition as the number of software firms increases). In CG when the value of additional software is small, hardware is differentiated, or there are few software varieties, the unique result is non-standardization. The only equilibria entail standardization when the value of additional software is large, hardware is not differentiated, or there are lots of software varieties.

The main welfare result of CG is that when consumers place a high enough value on software variety, software companies, to avoid competition, support both hardware technologies even though consumers would be better off under standardization. Insufficient standardization results when there is sufficient hardware differentiation, relative to network effects, that a hardware technology is viable with a single software firm, but only for strong network effects and not too much differentiation. Insufficient standardization also occurs in settings with direct network effects (Farrell and Saloner 1986).

In CG network effects are driven by a love of variety. Consumers assemble systems comprised of one unit of hardware and one unit of software. Their valuation of the hardware rises as the number of compatible software varieties increases because they can consume more systems.[1] Unlike CG, the Clements' model is a matching model and consumers do not have a love of variety. Rather in Clements consumers have a single ideal system consisting of one unit of hardware and one unit of software that they consume (as in the components approach of Matutes and Regibeau (1988)). When an additional software firm in the Clements' model supports a hardware technology, the advantage to consumers is a lower price and reduced mismatch costs. As in CG there is a demand effect and a competitive effect when a firm switches from one hardware technology to another.

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* Corresponding author at: Department of Economics, University of Calgary, Calgary, Alberta, Canada T2N 1N4.
*E-mail address:* jrchurch@ucalgary.ca (J. Church).

[1] See Church and Gandal (2005) and Church et al. (2008).

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Indeed the competitive effect is larger, since rather than just a reduction in market share (as in CG), there is also a reduction in price.[2]

In the Clements' model it is for small numbers of firms, limited hardware differentiation, or large software differentiation that the only equilibria are standardization. For large numbers of software firms, small software differentiation, or large hardware differentiation the unique equilibrium involves multiple networks. The results with respect to hardware and software differentiation (or benefit) are the same as CG. The difference is with respect to the number of firms. Clements gets standardization with a relatively small number of firms, CG multiple networks. Clements gets multiple networks with a large number of firms, CG standardization.

One of Clements' main results is that unlike direct network effects, increases in the size of the market (or reduction in the fixed cost of software) do not, in the case of indirect network effects, make standardization more likely (Clements Result 1).[3] Clements concludes the following (Clements 2004, p. 639 footnotes omitted):

- ". . . standardization is less likely for a greater number of software firms. This is the opposite of Church and Gandal's (1992) result."
- "Under direct effects, a larger mass of consumers encourages standardization; the opposite is true under indirect effects."
- "Under indirect effects, the mass of consumers determines the total number of software firms, and a large number of firms hinders standardization."

Moreover, his welfare conclusions are also the exact opposite of CG. Rather than excessive variety, Clements finds that indirect network effects are associated with excessive standardization (Clements Result II).[4]

The two Clements' results discussed above are counter-intuitive and, if correct, remarkable. We do not believe they are correct. The reason why the first is remarkable is that it does not appear to be consistent with network effects. For standardization to be an equilibrium, deviation by a software firm to another network cannot be profitable. The profitability of such a deviation presumably should be decreasing in the extent of network benefits enjoyed by consumers and these will be greater the larger the number of software firms. Indeed, in this comment, we show that neither Clements' Result I nor Clements' Result II are correct. Using Clements' model,[5] we find, consistent with CG, that (I) standardization is more likely as the number of software firms increases and (II) when the market equilibrium is either multiple networks or standardization, there is never excessive standardization, but there could be insufficient standardization. There is a region of the parameter space where consumers would be better off if there was standardization but the unique equilibrium involves multiple networks. Thus, both models of direct network and indirect network effects have the same important welfare result: when the only market equilibria entail standardization, it is efficient. The inefficiency in both models of direct and indirect network effects is the tendency for there to be too little standardization when the unique market equilibrium involves multiple networks.

## 2. The Clements' model

To recap the assumptions in the Clements' model: hardware is horizontally differentiated as per Hotelling with $X$ at the left end of the unit line and $Y$ at the right end. Consumers' preferences are distributed uniformly. The density of consumers is $A$. The mismatch cost for hardware is $t_h$. Consumers also buy a single variety of software. Consumers' preferences for software are distributed uniformly on the unit circle. We assume that each hardware firm supplies a sole variety of software.[6] We denote the number of independently supplied software varieties for network $j$ as $N_j$. Thus, the total number of varieties for network $j$ will be $N_j+1$. We assume that software varieties are distributed at equal intervals around the unit circle. The mismatch cost for software is $t_s$. The anticipated mismatch costs of software for a consumer, on the basis of which they make their adoption decision, are $t_s/(4(N_i+1))$, where $N_i$ is the expected number of independent software varieties for hardware $i$, $i=X, Y$. This follows immediately from observing (i) that minimum mismatch costs are 0, (ii) that maximum mismatch costs are $t_s/(2(N_i+1))$, and (iii) that the distribution of consumer preferences is uniform.

### 2.1. Consumers

The utility of a consumer that purchases hardware $X$ is

$$U^X = U^0 - p^X - at_h - p^{sx} - t_s/(4N_X+4) \tag{1}$$

and for hardware $Y$,

$$U^Y = U^0 - p^Y - (1-a)t_h - p^{sy} - t_s/(4N_Y+4) \tag{2}$$

where $a$ is the location of the consumer as measured from hardware $X$, $p^j$ the price of hardware $j$, and $p^{sj}$ the price of software for hardware $j$. The Nash equilibrium software price for hardware $j$ is

$$p^{sj} = c_s + t_s/\left(N_j+1\right) \tag{3}$$

where $j=X, Y$.[7] Without loss of generality we assume that the unit cost of software ($c_s$) equals zero. Denote the fixed cost of development of an independent software variety as $f$.

By assumption, hardware is priced competitively and the marginal cost of the two technologies is the same, so the marginal consumer is defined, from Eq. (1) through Eq. (3) as

$$a = (1/2) + (5/8)(t_s/t_h)(1/(N_Y+1) - 1/(N_X+1)). \tag{4}$$

### 2.2. Free-entry number of software firms

There is free-entry of software and two relevant cases. In the first case all independent software firms support only one of the two hardware technologies ($N_j=N$, $N_i=0$). $U^0$ is assumed to be sufficiently large that only the technology supported will be adopted and that it

[2] CG model software consumption following the monopolistic competition model of Dixit and Stiglitz (1977). Clements models software consumption using the circle model of Salop (1979).

[3] See Clements' Corollary 2 (iii) and (iv) at p. 638.

[4] See Clements Corollary 5 at p. 641.

[5] We use a variant of Clements' model that insures when we consider the incentive for deviation by an independent software firm from a standard that there is competition on the alternative network. The Nash equilibrium software price that Clements uses is only valid if there is competition. We insure competition by assuming that hardware firms provide a single variety of software. See footnote 7.

[6] All other assumptions are as in Clements except the assumption of a single variety of software provided by the hardware firm. See footnote 7 for why this is required.

[7] As per Salop (1979), in Clements and in an Appendix available from the authors Eq. (3) is used for the software price even if there is a single variety of software. This would not be the profit maximizing price if there was a monopolist in software, i.e., a single variety. It is for this reason that we have deviated from Clements' original formulation to allow for a "default" provision of a variety by the sponsor of a standard. Hence Eq. (3) will apply whenever there is a single independent source of software. The Appendix shows that our critique holds even if Eq. (3) is used for monopoly software provision and the software variety supplied by a hardware firm is zero, as per Clements' analysis. In this comment proper we adopt a specification for which Eq. (3) is in fact the Nash equilibrium price in software. Our critique of Clements does not depend on whether there is a default software variety or not.