Economies with Replicable Objects

William Phan*

February 27, 2013

Abstract

Agents can replicate and transfer indivisible objects. Replication and transfer take a unit of time, and agents collectively have a limited amount of time. How should agents transfer objects? We study *efficiency*, *strategy-proofness*, *withholding-proofness*, and introduce a new axiom based on the concept of reciprocity. We show that no mechanism satisfies all four properties.

Extended Abstract

A company may generate local information (code, data, etc.) stored in geographically distinct servers during the day and have a limited window of opportunity to update other servers at night. Each location may wish to update its own servers with information stored on other servers. How should the servers transfer amongst themselves?

More generally, consider the exchange of electronic files between agents. Files which are partially transferred may be corrupt or useless; hence, they are indivisible goods and we refer to them as objects. Objects may be perfectly replicated and transferred from one agent to another. We abstract away arbitrary size of files and individual transfer speeds—all objects require one unit of time to transfer from one agent to another. Object transfer may then be represented by *rounds* during which an agent may simultaneously send one object and receive one object. During subsequent rounds, each agent may transfer objects he received in previous rounds. A finite number of rounds is assumed, after which each agent consumes his bundle. How should agents transfer amongst themselves?

Following the axiomatic method, we focus on several desirable properties and their implications on the space of rules. *Efficiency* ensures no resources are wasted. *Strategy-proofness* ensures agents may not benefit from reporting false preferences . To encourage agents to maximally contribute to the system, *withholding-proofness* requires each agent's best interest is to contribute all the resources he has (in this case, objects). The next axiom is based on the concept of reciprocity between agents. Roughly, if i transfers an object to j, then i has the "minimal right" to one of j's objects. The *reciprocity lower bound* says an agent must be at least as well off as his "minimal rights" from each recipient of his object. We show that the four properties are incompatible.

*University of Rochester, Department of Economics. E-mail: wphan@z.rochester.edu.

The economy with replicable objects is inspired by technologies which utilize end user resources to distribute electronic files. Incentives were immediately recognized as important considerations in building such networks—in particular, the incentive to contribute resources. Adar & Huberman (2000) studied a popular file-sharing network and found that a large number users contributed nothing. Our justification for *withholding-proofness* stems from this pervasive free-riding in applications. From Feldman & Chuang (2005):

> There is growing recognition among distributed system designers that the ultimate success of their system depends not just on traditional technical considerations such as performance, robustness and scalability, but also on economic considerations such as incentive compatibility.

In other words, they suggest a mechanism design approach. One of their proposals is a bilateral reciprocation between agents—if you transfer to me, then I will transfer to you. Our *reciprocity lower bound* property formally embodies this notion. Feldman, Papadimitriou, Chuang, & Stoica (2006) studies a model where agents where agents are characterized by a generosity parameter and decide whether or not to contribute a homogenous resource to the system. They suggest "resource heterogeneity" as an extension—we consider that here.

The model in this literature closest to ours is Aperjis & Johari (2006). Each agent is endowed with a set of objects and an upload capacity rate; their consumption space is a list of *rates of download* indexed by their desired objects. They propose a price mechanism to determine a list of rates of download and achieve *efficiency* through a competitive equilibrium. Agents implicitly stay until they receive all their desired objects. Our main modelling differences are the abstraction of agents' preferences over time, abstraction arbitrary capacity constraints, and assumption of finite rounds of transfer. We arrive at a model closely related to the discrete resource allocation literature in economics as initiated by Shapley & Scarf (1974).

References

[1] E. Adar and B. A. Huberman. Free riding on gnutella. First Monday, 5.10, 2000.

[2] C. Aperjis and R. Johari. A peer-to-peer system as an exchange economy. GameNets, 2006.

[3] M. Feldman and J. Chuang. Overcoming free-riding behavior in peer-to-peer systems. ACM Sigecom Exchanges 6.1, 2005.

[4] M. Feldman, C. Papadimitriou, J. Chuange, and I. Stoica. Free-Riding and Whitewashing in Peer-to-Peer Systems. IEEE Journal on Selected Areas in Communications 24.5, 2006.

[5] L. Shapley and H. Scarf. On cores and indivisibility. Journal of Mathematical Economics 1.1, 1974.