AVEA

Advanced Virtual Economy Applications

A Summary of Project Final Report

HELSINKI
INSTITUTE FOR
INFORMATION
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1 Introduction

In 2007, the AVEA project proposal called for a new research effort into "so-called virtual property, artificially scarce digital objects that have rapidly become a viable business model for software products and online services." Gold farmers and real-money traders in massively-multiplayer online games had recently broken into popular consciousness. There was an expectation that virtual economies were going to continue to expand in one way or the other.

Helsinki Institute for Information Technology HIIT and the Finnish interactive media industry had already had a good start in grasping the phenomenon thanks to some successful early ventures and research projects. Now was a time to push on and take part in creating the next wave of the phenomenon.

The AVEA project plan put forward the following research questions: *What drives the value of virtual goods and how can we model it? How can we measure economic activity in virtual economies? How can the virtual economy model be extended to new platforms and non-gaming applications?* These questions reflect thefact that while significant revenues were already being made in the virtual goods business, there was no comprehensive understanding of why the goods were so valuable, and whether some opportunities for value creation remained unexploited. Edward Castronova at the University of Indiana was putting forward GDP estimates for virtual economies, but game operators were not convinced that tools from national economies were the correct ones for managing virtual economies. Furthermore, while the prevailing virtual economies at the time were massively-multiplayer online games, we were questioning whether the same principles could not be adapted for other platforms and purposes, such as mobile and serious applications. During the three years that then followed, virtual goods, currencies and economies saw almost explosive growth on the Western market. Virtual goods sales became the dominant revenue model for online and especially social games, and many game developers referenced the publications of this well-timed project in designing their offerings. Virtual economies not involving real money also increased in complexity, and the project yielded an alternative to GDP for measuring them. The development of mobile virtual economy prototypes during the first project year heralded the eventual commercial breakthrough of the virtual goods model in mobile gaming applications, although this breakthrough did not happen in Finland.

This report is intended to provide an overview of the main research streams in the project and their key outcomes. Following the structure established by the research questions in the project plan, the report is organised into three sections: *Value, Measuring* and *Applications*. Each section contains three chapters that address the research questions from different angles by summarising work conducted in the project. Each chapter is also prefaced by a one-page summary.

The project resulted in no less than 20 scholarly publications, including articles and papers published in some of the leading venues of digital social sciences and HCI research. One PhD thesis and a total of four Master's theses were completed during the project. A number of manuscripts are also still being worked on. This is a significant volume of publications for a three-year research project with a core team of only a handful of researchers. In part it reflects the fact that digital scarcity is a novel research topic, and is taking by surprise some academic disciplines still grappling with the implications of digital abundance. HIIT and the individual researchers involved in the project are now exceptionally well positioned to continue work on these topics.

Furthermore, AVEA's publication success also certainly reflects the project's strong element of international collaboration. HIIT's main partner in the project was the Distributed and Ubiquitous Computing Laboratory at Waseda University, Tokyo, lead by professor Tatsuo

Nakajima. Thanks to professor Nakajima's team's expertise in pervasive technologies, serious games and realistic prototyping, we were able to conduct applied research and user studies that were published in such venues as the prestigious ACM International Conference on Ubiquitous Computing. As part of the project, we also developed the Virtual Economy Research Network into an even more prominent hub and forged new international links that are already proving their value in follow-up research initiatives.

We would like to express our strong gratitude to the companies that took part in the AVEA consortium: Nokia, CCP Games, SWelcom and EveryPlay. CCP provided us with unprecedented access to a virtual economy data set that continues to yield results in follow-up research, for which we are very thankful. Finally, we would like to express our extreme gratitude to the Finnish Funding Agency for Technology and Innovation Tekes, for their crucial support in the form of funding as well as networks and advice, without which the project would not have been possible.

On behalf of the project team,

Kai Huotari
project manager

Vili Lehdonvirta
editor

7 June 2010

Section I: Value

2 Understanding consumer demand for virtual goods

Vili Lehdonvirta

Why do people spend real money on game items, virtual currencies and other virtual goods? This question is central for businesses seeking to benefit from the phenomenon, as well as for developers aiming to utilise the persuasive allure of virtual goods for other ends. It is also part of the general question of what kind of impact information and communication technologies are having on society.

In popular discussions, virtual goods are often seen as illusory, unreal or even "nonexistent". They are contrasted with "real" goods, which are smart, useful and valuable. But a review of social scientific literature on consumption shows that people buy material goods for a multitude of reasons, and it is difficult to say whether most of them are really smart or "rational".

Commonly consumption is associated with the satisfaction of needs, such as need for food and shelter. In reality, we consume much more than needed by any objective measure, and in ways that do not always contribute to safety or well-being. Consumption behaviour is easier to understand if we look at it as a way of signaling one's position in society and fulfilling obligations towards others; as a vehicle for experiences and expression; and as a tool for addressing arbitrary goals, often constructed by marketing. For example, there would hardly be a market for business suits and neckties had they not become a mark of a businessman, a mandatory dress in many business occasions, and a tool for boosting self-confidence. In physiological terms, the necktie and the fancy suit are unnecessary and uncomfortable.

Interviews, surveys and observations of online game players and virtual world participants conducted in the project show that virtual goods are acquired for the same physiologically frivolous yet sociologically serious reasons. *Habbo* users use virtual furniture to express and impress, *EVE Online* players find powerful ships and components vital for their arbitrarily determined goals, and participants in *Cyworld* send virtual birthday gifts to each other to fulfil social norms. As a result, there is demand for virtual goods in these environments. When demand interacts with supply on a market, a price is formed – measured either in time that participants must invest to obtain a good, or increasingly, in real money. This is the economic value of virtual goods: just as and only as real as the economic value of material goods. The supposed inferiority of virtual goods stems from the fact that they only exist inside digital environments, but by the same token, material goods only exist in pockets of the material environment – while more and more aspects of human life are going digital.

The chapter below presents a sociological account of the different roles virtual goods play in people's lives, which acts as a foundation for understanding their business and design.

3 Virtual good sales as a business model

Juho Hamari

The sales of virtual goods became a viable revenue model for game operators when games started to be increasingly published through digital channels. Digital environment diminishes costs of shipping content and hence game products could be sold in smaller parts (e.g. episodic gaming and virtual goods), whereas in physical channels games are sold as a whole because the distribution is significantly more expensive.

Dividing a game product to smaller purchasable parts also enabled serving players with differing willingness to pay. Most services selling virtual goods let players enter services for free and on the other hand do not limit the amount of how much players can spend in the game. Business models selling game in boxes or requiring a monthly fee have a fixed amount of money that players have to spend and hence only a certain player base can be acquired.

Imagine if the game developer behind Monopoly tabletop game started selling virtual goods or, in other words, in-game artefacts, such as "get out of prison" cards, for real money. In this situation it becomes highly tempting for the developer of the game to alter the game mechanics for economic benefit, for instance, by raising the probability of players ending up in prison and hence increasing the frequency of players requiring the "get out of prison cards".

In virtual goods sales business model this kind of interdependence between the design of the rules of the game and the goal of generating revenue by selling virtual goods exists. This implies that the game design turns into business design for firms selling virtual goods, which further creates some problematic conflicts between the fun of the game and continuous attempts to sell virtual goods to users, as seen in the Monopoly example.

However, not all sold virtual goods are of functional nature, but for instance most offer only aesthetic improvements. In practice, the so-called virtual good sales or microtransactions revenue model involves selling some form of virtual items, "avatars" or currencies to the users of an online service. Perhaps most frequently, the object sold for real money is a virtual currency, which is then exchanged for virtual items. The items can range from weapons and armour in online games to clothes in virtual worlds and simple two-dimensional graphical badges in social networking sites. The items are used as part of gameplay or to fulfil similar social and aesthetic functions as physical commodities are used for elsewhere in consumer culture.

Nevertheless, whereas traditional industries create value primarily through content, that is products and services, a significant part of value creation efforts of the virtual goods sales model is directed towards designing the context, in which the virtual goods are used. For most traditional businesses the context is an exogenous, bounding factor for the business, but for virtual goods business the context is key in creating value for virtual goods through design of the environment.

4 Game design as marketing

Juho Hamari and Vili Lehdonvirta

Selling virtual goods for real money is an increasingly popular revenue model for massively-multiplayer online games (MMOs), social networking sites (SNSs) and other online hangouts. In this paper, we argue that the marketing of virtual goods currently falls short of what it could be.

Game developers have long created compelling game designs, but having to market virtual goods to players is a relatively new situation to them. Professional marketers, on the other hand, tend to overlook the internal design of games and hangouts and focus on marketing the services as a whole. To begin bridging the gap, we propose that the design patterns and game mechanics commonly used in games and online hangouts should be viewed as a set of marketing techniques designed to sell virtual goods. Based on a review of a number of MMOs, we describe some of the most common patterns and game mechanics and show how their effects can be explained in terms of analogous techniques from marketing science. The results provide a new perspective to game design with interesting implications to developers. Moreover, they also suggest a radically new perspective to marketers of ordinary goods and services: viewing marketing as a form of game design.

In past studies, the question of why people buy virtual goods has mainly been approached from the perspectives of the attributes of the virtual goods and the decision processes of the buyers. However, as the value of the virtual goods is largely dependent on the given virtual world or service they are in, the research has to also take into account the context and the design of the virtual world to fully understand motivations for buying virtual goods.

The value of many virtual goods can be derived from the environments where they are used. This is especially the case in MMOs, where most virtual goods increase players' performance and provide functionality. In these situations the operator of the virtual world can manipulate the "needs" of players that stem from the requirements designed into the game. This type of design bears close resemblance to marketing, which implies that, consciously or not, game designers have a role in marketing virtual goods through design. For example the following design patterns are used for segmenting and differentiating the virtual goods market: stratified content, avatar types, increasingly challenging content and explicit limitations to virtual goods that restrict their use based on avatar's attributes.

Physical products deteriorate and break in time, which creates a possibility to resell products to customers. Some firms even attempt to shorten the lifespan of products intentionally. However, with virtual items, as with other digital goods, there is no technical reason for products to deteriorate. Games with their rules and lore enable firms to introduce planned obsolescence by justifying it through the game mechanics. Similarly, there is no technical reason for virtual goods to be scarce, because they can be copied indefinitely. However, abundant rewards would remove the core premise of challenge from games. Many of the methods for monetising games with virtual goods are based on scarcity, such as, so called "sinks" that remove virtual goods from the circulation of in-game economy and from possessions of user, hence creating incentive for repeated purchases.

Section II: Measuring

5 Macroeconomic indicators in a virtual economy

Tuukka Lehtiniemi

Virtual worlds contain systems of resource allocation, production, and consumption that are often called *virtual economies*. A virtual world operator has an incentive to monitor the economy, and users and outside observers benefit from temporal and cross-economy comparisons.

Standard methodology of computing macroeconomic aggregates would allow this analysis, but such methodology is currently unavailable. I fill this gap by employing the concepts of national accounting. I focus on virtual economies where the production of new virtual goods takes place as the users expend inputs to produce predetermined outputs along predetermined production paths.

Previous attempts at measuring the aggregate production of a virtual economy have been based on non-standard methods and externally collected data. In virtual economies the operator can collect extensive data automatically—a characteristic feature that should be reflected in any standard accounting scheme.

Macroeconomic aggregates for a national economy are computed using the System of National Accounts, which is intended for measuring a national economy vis-à-vis the rest of the world. In a virtual economy context, by contrast, I make the distinction between production by the users and creation of goods by the virtual world code. These principles result in an aggregate measure called the Gross User Product, which measures the aggregate output of production activities by the users. I measure GUP for the virtual economy of EVE Online, based on extensive log data collected by the operator. The demonstrated method is generalizable for quantifying virtual economies on the macro level.

6 Econometrics: the case of gender and wealth

Tuukka Lehtiniemi and Vili Lehdonvirta

In almost every economy in the world, women's income and wealth are lower than men's. There is considerable debate as to whether this disparity is attributable to biological factors (physical abilities, childbearing), lifestyle choices (choice of education and occupation, number of hours worked) or structural and individual discrimination against women (lower pay for the same work).

Empirical studies have not been able to settle the question because of the difficulty of distinguishing between choice and discrimination in statistical data. In this study, we examine the question using data from a so-called virtual economy: a large-scale economic simulation taking place in a massively-multiplayer online game with over 300 000 participants. The advantage of this approach is that we can distinguish between the economic actors' physical gender and the gender of the guise through which they appear to other actors. This allows us to examine the economic consequences of "being female" and "appearing female" separately. The results lend tentative support to both choice and discrimination: female players make less wealth out of virtual resources given to them, but female players using a male avatar are better off than female players using a female avatar.

The analyses presented in this chapter are conducted using the *EVE Online* data set provided by CCP Games. In an instance of follow-up research stemming from the AVEA project, we are now collaborating with researchers from the University of Southern California to conduct equivalent analyses on the massively-multiplayer role-playing game *EverQuest 2*. The combined results will enable us to put forward a strong contribution to the debate concerning gender and wealth, whilst demonstrating the unique value of virtual economies for social scientific research.

7 Virtual economies and the theory of large games

Juha Tolvanen

In virtual worlds, as in any real-world social context, users' behavior is strongly affected by the behavior of other users. The virtual property I purchase, the avatar I choose, the guild or corporation I commit myself to and even the hours I spend in each service are all affected by the choices of other users. This interdependence in users' actions implies that even a profound understanding of users' motivations, valuations and other socio-economic fundamentals does not necessarily translate into an ability to predict and explain how users behave. Luckily there is a methodological framework known as game theory, which can be used to transform the aforementioned socio-economic fundamentals and our understanding of the laws governing the interdependence between the users' choices and preferences into actual predictions on user behavior.

Another characteristic feature of virtual worlds is that users' preferences often depend on the actions of very large masses of other users. For standard game theoretic models this is often problematic as they tend to become extremely hard to solve. However, during the recent years the theory of large games has seen many advances. Scientists have been able to develop heuristic models that are easier to solve than the more "correct" models and that can be shown to approximate well the behavior in the hard-to-solve standard models. In this paper we first give a short presentation of the theory of large games in general. Then we continue to show how one of the recent heuristic models can be applied to studying resource farming in massively multiplayer online role-playing games. We also briefly mention other possible questions rising in virtual worlds that could be studied using the same heuristic.

Section III: Applications

8 EcoIsland: a virtual economy for sustainable living

Miyuki Shiraishi, Yasuyuki Washio, Chihiro Takayama, Vili Lehdonvirta, Hiroaki Kimura and Tatsuo Nakajima

Public and private efforts to steer individuals' behaviour towards more environmentally sustainable practices usually rely on advice and education, but there are psychological limits to the ability of education alone to effect behavioral change. Even when a person full-well knows that a particular behavior is detrimental enough to their long-term well-being to offset any possible short-term benefits, they may still irrationally choose the short-term indulgence. Future consequences, while widely known, are easily ignored in the present.

The EcoIsland system was developed as part of the AVEA project's collaboration with the Distributed and Ubiquitous Computing Laboratory at Waseda University, Tokyo, Japan. It leverages techniques from games and virtual economies to motivate families to adopt more environmentally sustainable lifestyle choices. In practice, it consist of a low-power display unit installed in the kitchen or living room that visualises the family's estimated CO_2 emissions using a sinking island metaphor. Each family member is represented by a character on the island, and members interact with the system using mobile phones.

A key feature of the system is a virtual currency, which the family members can use to purchase items to decorate their virtual island. Moreover, the virtual currency is used as a medium of exchange on a family-to-family emissions trading market. Emissions trading is usually used on an inter-governmental or industry level to control harmful emissions. The basic idea is that each participant has an agreed-upon quota of emissions they are allowed to release into the atmosphere. Any emissions in excess of that quota must be justified by purchasing unused emission rights from participants who pollute less. Similar to environmental taxes, this creates an economic incentive to reduce emissions. Unlike taxes, however, the market encourages emissions reductions in places where it is most efficient to do so, and can thus lead to greater reductions.

EcoIsland takes the emissions trading idea from industry circles and applies it to individual families, who volunteer to cap their CO_2 emissions. This is made possible by ubiquitous computing technologies that interact with the users and enable real-time market communications with other families. In a real-life user study with six families lasting over four weeks, different persuasive mechanisms built into EcoIsland had a significant positive influence on the family members' environmental behaviour.

9 UbiPay: influencing consumer behaviour through points and pricing models

Vili Lehdonvirta, Hayuru Soma, Hitoshi Ito, Tetsuo Yamabe, Hiroaki Kimura and Tatsuo Nakajima

In everyday purchases from lunch to subway tickets, cash has been largely replaced by electronic payment methods such as credit cards and stored value cards. The latest development in this area is mobile payments: using mobile phones to initiate, activate, and/or confirm payment transactions. For example, the Japanese "Wallet phone" system allows most mobile phones sold today to act as an alternative to cash and credit cards, as well as incorporate the functions of membership and loyalty point cards. According to Gartner, the number of mobile payment users worldwide reached 33 million already in 2008.

Compared to earlier payment methods, advanced mobile phones have many interesting features: the ability to sense surroundings using sensors such as GPS and accelerometers, the ability to communicate with nearby devices wirelessly, and the ability to run programs and store data. In the UbiPay project, conducted as part of the AVEA project's collaboration with Waseda University, we explored the use of these features to create next generation mobile payment solutions. On one hand, we sought to improve the speed and usability of payment transactions.

On the other hand, we introduced ideas from games and virtual economies to turn payments into a tool for marketing and customer relationship management.

Four different concepts were developed: UbiPay, UbiRebate, UbiReward and UbiTrade. In the UbiPay concept, sensors and wireless communications are used to conduct micropayments for things such as air conditioning without any interruption to the user. This allows the separate commercialisation of microservices that are usually bundled with other services. In the UbiRebate concept, users get automatic and transparent microrebates for saving resources and forgoing the use of bundled services. Resource use is detected using sensors in the phone and the environment. In the UbiReward model, users are automatically rewarded with loyalty points and other virtual currencies for taking suggested actions, such as vacating a seat quickly at a crowded lunch restaurant. In the UbiTrade model, consumers bid points for scarce resources such as movie tickets or seats in a crowed restaurant.

The UbiPay and UbiRebate concepts were validated with realistic prototypes in two separate user studies. The results suggest that both concepts deliver value to the user in the form of decreased transaction costs (effort required to conduct payment transactions) and have a significant impact on payment behaviour. The various risks of ubiquitous payment and point systems were also considered.

10 Virtual value chain dynamics in the changing media business

Herkko Hietanen and Marko Turpeinen

We understand pretty well how the value of physical objects is formed. The value chains and networks however are more dynamic when the consumed service is immaterial. Industries that have been between physical and immaterial world have seen disruptions when their products have became virtual. The communications industry is being disrupted as intelligence and control — once centralized — shift to the edges of the network. MIT's Communications Futures Program has a Value Chain Dynamics working group, which seeks to understand the business models and economics associated with these changes in network functionality, and has developed a methodology for systematically exploring the technology, business, and policy dynamics of new business models. AVEA researcher Herkko Hietanen joined the group as a visiting scientist in August 2009. The goal of the visit is to co-operate with the Value Chain Dynamics group in developing new methods for analyzing the changes in value creation and distribution.

During the last research year the group analyzed the changes in the television advertising and time-shifting functions. Many of the central concepts of television are changing as television moves from broadcast model to then Internet. Many of the economics of broadcasting no longer apply when the content is consumed from online sources. Internet has also meant that physical objects like recorders can be located in cloud. Consumers receive the same service but the object is virtualized. The technology for storing video in the cloud is trivial and there have been several video storage service surfacing to market both in Finland and abroad. As the competition gets tougher these services will have to develop social connection tools and virtual services to compete for consumers attention.

As the television is no longer tied to the restrains of the broadcast technology the television advertising is also going to face big changes in the near future. Advertisers will no longer pay for reaching an audience but demand access to tightly defined target groups. The advertiser will likely move from paying for the viewers attention into paying for sales that go through because of the advertisement. The virtual worlds and social networks will be in a great position to serve advertisers as they can provide access to their users' interests, friends and past behavior better than any other advertising platform.

Appendix: List of scholarly publications produced in the AVEA project

Vili Lehdonvirta (2010) Virtual Worlds Don't Exist: Questioning the Dichotomous Approach in MMO Studies. *Game Studies*, vol. 10, no. 1.

Juho Hamari & Vili Lehdonvirta (2010) Game Design as Marketing: How Game Mechanics Create Demand for Virtual Goods. *Int. Journal of Business Science and Applied Management*, vol. 5, no. 1, pp. 14-29.

Juha Tolvanen (2010) *Approximating Competitive Games with a Large Number of Players*, Master's Thesis, University of Helsinki.

Juha Tolvanen (2010) *Mathematics of Large Competitive Games*. Master's thesis, University of Helsinki.

Tetsuo Yamabe, Vili Lehdonvirta, Hitoshi Ito, Hayuru Soma, Hiroaki Kimura, Tatsuo Nakajima (2010) Activity Based Micro Pricing: Realising Sustainable Behavior Changes Through Economic Incentives. *Proceedings of the Fifth International Conference on Persuasive Technology (Persuasive 2010),* Copenhagen, Denmark, June 7-10.

Tuukka Lehtiniemi (2009) Measuring Aggregate Production in a Virtual Economy Using Log Data. *Journal of Virtual Worlds Research*, 2(3).

Juho Hamari (2009) Virtual goods sales: new requirements for business modelling? Master's thesis, University of Jyväskylä.

Vili Lehdonvirta (2009) Virtual Consumption. *Publications of the Turku School of Economics*, A-11:2009, Turku.

Vili Lehdonvirta, Terhi-Anna Wilska & Mikael Johnson (2009) Virtual Consumerism: Case Habbo Hotel. *Information, Communication & Society*, vol. 12, no. 7, pp. 1059-1079.

Vili Lehdonvirta (2009) Virtual Item Sales as a Revenue Model: Identifying Attributes that Drive Purchase Decisions. *Electronic Commerce Research*, vol. 9, no. 1, pp. 97-113.

Vili Lehdonvirta, Hayuru Soma, Hitoshi Ito, Tetsuo Yamabe, Hiroaki Kimura & Tatsuo Nakajima (2009) UbiPay: Minimizing Transaction Costs with Smart Mobile Payments. *Proceedings of the 6th International Conference on Mobile Technology, Application & Systems (Mobility 2009),* Nice, France, September 2-4. New York: ACM.

Tetsuo Yamabe, Vili Lehdonvirta, Hitoshi Ito, Hayuru Soma, Hiroaki Kimura, Tatsuo Nakajima (2009) Applying Pervasive Technologies to Create Economic Incentives that Alter Consumer Behavior. *Proceedings of the 11th International Conference on Ubiquitous Computing (Ubicomp 2009),* Orlando, Florida, September 30-October 3. New York: ACM, pp. 175-184.

Miyuki Shiraishi, Yasuyuki Washio, Chihiro Takayama, Vili Lehdonvirta, Hiroaki Kimura, and Tatsuo Nakajima (2009) Using individual, social and economic persuasion techniques to

reduceCO2 emissions in a family setting. In: S. Chatterjee and P. Dev (eds), *Proceedings of the 4th International Conference on Persuasive Technology (Persuasive 2009),* Claremont, California, April 26-29. New York: ACM, pp. 130-138.

Miyuki Shiraishi, Yasuyuki Washio, Chihiro Takayama, Vili Lehdonvirta, Hiroaki Kimura & Tatsuo Nakajima (2009) Tracking Behavior in Persuasive Apps: Is Sensor-Based Detection Always Better Than User Self-Reporting? Poster presented at The 27th International Conference on Human Factors in Computing Systems (CHI 2009). *Proceedings of the 27th international conference extended abstracts on Human factors in computing systems,* Boston, MA, USA, April 4-9. New York: ACM, pp. 4045-4050.

Tuukka Lehtiniemi (2008) Macroeconomic Indicators in a Virtual Economy. Master's thesis, University of Helsinki.

Vili Lehdonvirta & Tuukka Lehtiniemi (2008) Economics. In: Perron, Bernard & Wolf, Mark J. P. (eds), *The Video Game Theory Reader 2,* New York: Routledge, pp. 344-346.

Vili Lehdonvirta, Hayuru Soma, Hitoshi Ito, Hiroaki Kimura & Tatsuo Nakajima (2008) Ubipay: conducting everyday payments with minimum user involvement. Extended Abstracts *Proceedings of*

the 2008 Conference on Human Factors in Computing Systems (CHI 2008), Florence, Italy, April 5-10. New York: ACM, pp. 3537-3542.

Vili Lehdonvirta (2008) Virtual Worlds Don't Exist. Paper presented at *Breaking the Magic Circle: Game Research Lab Spring Seminar,* Tampere, Finland, April 10-11.

Chihiro Takayama & Vili Lehdonvirta (2008) EcoIsland: A System For Persuading Users To Reduce CO2 Emissions", paper presented at Pervasive Persuasive Technology and Environmental Sustainability Workshop, 6th International Conference on Pervasive Computing. *Pervasive 2008 Workshop Proceedings,* Sydney, Australia, May 19, pp. 113-119.

Chihiro Takayama, Vili Lehdonvirta, Hiroaki Kimura & Tatsuo Nakajima (2008) ECOISLAND: A System for Persuading Users to Reduce CO2 Emissions. Poster presented at Tenth International Conference on Ubiquitous Computing (UbiComp 2008). *Proceedings of the 10th Ubicomp 2008 Adjunct Programs,* Seoul, Korea, September 21-24, pp. 30-31.

Unpublished working papers and papers in review

Juha Tolvanen & Elefterios Soultanis. (2010) Corrigendum and some further notes on "Large games and the law of large numbers" [Games Econ. Behav. 64 (2008), 1-34]. *Games and Economic Behavior.*

Tuukka Lehtiniemi & Vili Lehdonvirta. Examining economic disparity in a computer-mediated virtual economy: influence of player and avatar gender on wealth

Vili Lehdonvirta. Who buys virtual goods? A cross-cultural survey of Habbo users