2013

Development of a Decision Support System for Collective Stock Market Intelligence

John Campbell
University of Canberra, john.campbell@anu.edu.au

Byron Keating
University of Canberra, byron.keating@anu.edu.au

Information Systems: Transforming the Future

24th Australasian Conference on Information Systems, 4-6 December 2013, Melbourne

Proudly sponsored by

ACIS 2013 Principal Sponsor

Development of a Decision Support System for Collective Stock Market Intelligence

Research-in-Progress

John Campbell
School of Information Systems and Accounting
Faculty of Business, Government and Law
University of Canberra
Canberra, Australia
Email: john.campbell@canberra.edu.au

Byron Keating
School of Management
Faculty of Business, Government and Law
University of Canberra
Canberra, Australia
Email: byron.keating@canberra.edu.au

Abstract

Internet discussion sites have become an enduring feature of modern asset markets. While prior research demonstrated a strong link between communicative practices and market behaviour, more work is required to fully understand the processes that support knowledge co-creation in these environments. To address this gap, we propose a research project to (1) Identify the factors that drive communication and influence knowledge co-creation, (2) examine how systematic variations in these factors influence investment and trading decisions, and (3) develop a decision support system that combines communication analysis and "what-if" scenario modelling to forecast impacts on capital markets. The practical goals for this project are to help improve investor decision-making and assist regulators through better detection of market manipulation.

Keywords

Collective intelligence, stock market activity, decision support system, communicative practices.

INTRODUCTION

The Internet has become a core component of the communication infrastructure of financial markets around the world. The relative low cost and ease-of-access offered by Internet technology has given rise to a host of online investor services now commonly made available by stock exchanges, brokerage firms, banks, and investment advisers. Digital networks provide clear benefits over traditional stock market participation by enabling online access to knowledge resources and online trading accounts. Consequently, these networks have become common and enduring features of modern stock markets and have fundamentally altered industry competition by changing the way that financial corporations differentiate their services and product offerings (Choi et al. 2002).

Internet discussion sites (IDS) are a key part of this change as they provide ready access to information, and the knowledge, support and opinion of likeminded investors and traders. It is not uncommon in some IDS communities to observe small investors in discussion with top twenty shareholders of small and mid-tier listed companies, subject matter experts, experienced technical staff, directors and other company representatives.

During the past five years new applications have emerged with the aim of gleaning market-related intelligence from communities of interest. Examples include the Motley Fool's CAPS Community (www.caps.fool.com) and PIQQEM (www.piqqem.com). Both seek to harvest community expertise with the aim of identifying stock investment opportunities and are used by each organization to provide a premium source of information for subscribers. Other examples include Marketocracy Data Services who operate a "farm system" for novice traders to identify the best investors in the world (www.marketocracy.com), and EquitySplash who claim to be the world's first crowdsourced mutual investment fund platform (www.equitysplash.com).

Despite the recent progress made by such communities, IDS remain largely an untapped resource of market intelligence and insight. Modelling the wisdom and foolishness of like-minded investors could provide timing and market direction indicators that result in above average investment returns. Consequently, the overarching

objective of this project is to develop a decision support system (DSS) that can be used to model and interpret communication behaviour within IDS communities to distil beneficial market intelligence. Also, there is strong evidence that IDS can be used to manipulate others (Campbell and Cecez-Kecmanovic 2011). Consequently the DSS should help detect such activity and thereby assist regulators through better detection of market manipulation.

CONCEPTUAL FRAMEWORK

Despite the pervasiveness of financial IDS communities, there is very little research that has examined how the various elements of IDS-based communication can be used as a source of intelligence (Teschner and Weinhardt 2012). There is also a scarcity of research that examines the quality of the information that is generated from the perspective of IDS as collective human intelligence (Malone et al. 2010). This perspective highlights the diverse roles that IDS members play in a problem-solving process. These roles include providing factual data, undertaking independent research, decomposing problems and performing human program synthesis (Zhang et al. 2011). This project will address this deficiency by examining how stock market intelligence can be generated from financial IDS. In so doing, this study will help to create a more transparent and better informed market. Consequently, this research project has three aims:

1. Identify the factors associated with IDS-based communication that have the greatest influence on stock market trading activity.
2. Examine how systematic variations in these factors influence trading decisions and choices for different users and groups of users.
3. Develop and evaluate a DSS tool that combines communication analysis and what-if scenario modelling to predict movements in stock market activity.

An IDS typically represents a group of self-motivated individuals who share knowledge and information about a diverse range of topics, but largely those concerned with trading the shares of publicly listed companies. Financial IDS communities empower private investors by supporting synchronous and asynchronous text-based conversations about key securities-related topics, including but not limited to, trading strategies, tax implications, comparative assessments of stockbroker services, and private research.

Information and its dissemination are central elements in the traditional efficient market view of how financial markets operate (Fama et al. 1969). In an information efficient market, stock prices fully reflect all available information thus preventing any individual from identifying an over- or under-valued security and thereby obtaining a reward greater than normal given the risk of investment. In theory, the existence of IDS should enhance the information efficiency of the market by creating an environment where market information is continuously discussed and evaluated.

Our conceptual model (see Figure 1) presents the theorized relationships that support information sharing and the generation of collective intelligence. This model explores how the relationship between the elements of IDS-based communication (communicative practices, knowledge co-creation) and stock market trading activity is influenced by incentives, and the characteristics of users and the respective IDS community. This model posits that intent and consequences of information sharing within IDS communities is far more complicated than just providing a forum for the dissemination of stock market and company-specific information.

Prior research has shown that the communicative practices embedded within IDS postings can influence stock market activity (Gu et al. 2007; Lu et al. 2010). For example, several studies have reported that increased IDS posting activity is a proxy for market sentiment, and that it preceded significant changes in next-day trading volume and share price returns (Antweiler and Frank 2004; Tumarkin and Whitelaw 2001). A study by Clarkson et al. (2006) found that companies identified as takeover targets in IDS discussions were, on average, associated with subsequent positive abnormal stock price returns. A recently study by Campbell and Cecez-Kecmanovic (2011) also found that the nature (knowledge domain) and motivation (action orientation) of communicative practices within an IDS changed significantly over time and, most importantly, that these changes were strongly linked to trading behaviour.

Communicative practices within virtual communities have also long been thought to influence knowledge co-creation. Henri (1992) was amongst the first to examine the value of computer-mediated communication as a tool for collaborative learning. Henri's work relied on breaking down the transcript into "units of shared meaning" (a message or a part of it), and classifying these units according to critical-thinking phases of knowledge construction: cognitive and meta-cognitive actions. To this end, Gunawardena et al. (1997) provide a five-phase Interaction Analysis Model that focused on answering two questions: "What degree of knowledge construction is achieved by the cooperative group?" and "What degree of evidence is there that the knowledge of individual participants changes?" In general, the first question is answered by the dominant cognitive phase observed within

the transcript, while the second question is answered by individual expressions which directly relate to changes or expressions which demonstrate the application of changed knowledge (meta-cognition).

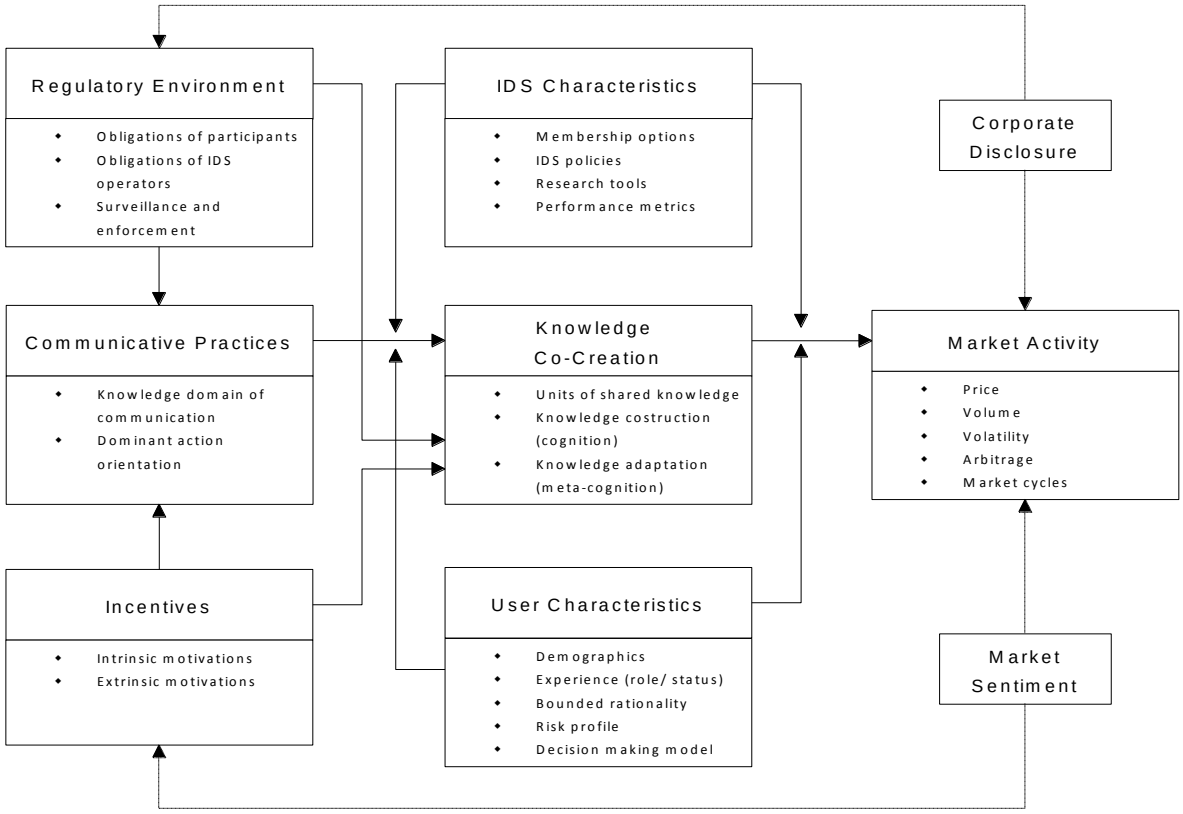

Figure 1: Collective stock market intelligence

IDS communication is viewed as a function of systemic (i.e., regulatory environment and IDS characteristics) and human factors (i.e., user characteristics and incentives). Together these factors influence and shape communicative practices and knowledge co-creation. The systemic context reflects the need for IDS-based communication to comply with the relevant jurisdictional regulation. The features and functionality of an IDS typically include options for membership, specific policies relating to conduct of users, as well as research and performance tools to assist users to evaluate information and source credibility.

Human factors such as bounded rationality and opportunism also come into play. IDS participants have limited information processing capabilities and do not have the resources or cognitive abilities to gather and evaluate all information about existing and future market outcomes (Cowan et al. 2004). Many will tend to act on intuition and emotion and make choices based on personal preferences or by simply choosing the first alternative that comes to mind (Frederick 2002) or avoiding any option that exceeds their personal risk tolerance (Kahneman and Tversky 1979).

IDS members bring different elements of themselves to their communities. Some will have substantial experience or expertise in relevant areas or a well-developed network of contacts in a particular sector. Participants also display a range of risk preferences and investment horizons (e.g., short-term trader versus long-term investor), and even dissimilar investment philosophies (e.g., technical versus fundamental). IDS communities are dynamic and evolving and this is revealed through the changing relationships between key members and the leadership roles they fulfil with the continuing support of other community members. These users often provide detailed intelligence about particular securities and trading strategies (Campbell et al. 2009).

Interaction between IDS participants is also influenced by underlying incentives. While some IDS users are motivated by a desire to inform and assist, others are motivated by a desire for personal gain and will seek to manipulate the flow of information for short-term reward. This kind of opportunistic behaviour is evidenced in the use of rumours. Van Bommel (2003) developed a model that articulated the economic incentives associated with rumours in financial markets. Based on the Kyle (1985) auction process, his model showed that an investor with private information has limited wealth and is unable to capitalize on their knowledge until this information is in the public domain. Through the use of rumours, investors can obtain advantage by selectively releasing

information to followers who then trade on this information. As the share price moves in the direction of the rumour the investor can profit by taking an opposite position when the price overshoots its true value. Campbell (2001) differentiates this strategy from "pump and dump" schemes where uninformed investors buy a thinly traded stock and profit from false rumours about the stock.

An underlying feature of this perspective is the credibility of the person spreading the rumour. In a repeated game, bluffing and cheating erode the reputation of the rumour-monger and eliminate any profits. Van Bommel concludes that on the whole, rumours must be of value as if they were only ever false they would not survive, and followers would not be able to profit from trading on these rumours. IDS participants trade on rumours because they have an expectation that messages posted may contain credible information. If messages consistently contained false rumour there would be no followers willing to trade on the information.

Finally, the dotted lines from “market activity” back to “incentives” and “regulatory environment” capture the circular nature of communication within financial markets. While we would anticipate that communicative practices can influence trading behaviour, the resulting market activity can have a corresponding, reciprocal effect on communication and knowledge co-creation via corporate disclosure obligations and changing market sentiment.

APPROACH AND METHOD

Our project adopts a four stage, sequential mixed methods approach (Cresswell et al. 2011) to inform the development of a DSS tool for collective stock market intelligence. The first stage has been completed. This initial pilot work demonstrated the value of communicative practices as a predictor of trading activity. The second stage will explore the impact of various systemic and human factors on communicative practices and information sharing. The third stage will examine the interplay between factors, and their respective impact on investment decisions. The fourth and final stage will operationalize the resulting combinatorial model through the development of a DSS tool. Each of these research stages are discussed in more detail below.

Stage 1: Pilot Phase

To provide an informed foundation for this study, we undertook a comprehensive review of the academic and practitioner literature in relation to Internet discussion sites and communicative processes within social systems. The aim of this review was twofold. First, we sought to identify the dominant communication processes used within an IDS. Second, we sought to understand how these communication processes impacted on sentiment and decision making. The literature review guided the development of conceptual framework (see Figure 1). This framework considers the impact of the characteristics of a typical IDS on collective intelligence and trading behaviour. As a first step in validating this model, we identified the dominant communication processes present within an IDS, and have demonstrated that these processes have a measurable impact on stock market trading activity (Campbell and Cecez-Kecmanovic 2011). The results demonstrated strong support for our use of text-based communication analysis as a tool for better understanding stock market fluctuations. Within our conceptual framework we acknowledge that different IDS provide different features and different levels of support. We would expect that such differences may impact on a user’s ability to evaluate the quality and reliability of information which is communicated within an IDS, and will ultimately influence whether users act on such information.

Stage 2: Exploratory Phase (Aim 1)

An important preliminary task relates to the selection of the focal IDS for our study. In choosing the focal IDS, consideration will be given to three main criteria: (i) length of operation, (ii) the composition of membership, and (iii) available performance metrics. The length of operation is important as we will be seeking to understand how changes in communication practices affect trading activity over time, and to identify the communicative patterns that underpin co-created knowledge and market activity. We intend to focus only on sites that have been in operation for more than 10 years. This length of time is important as it will provide a sufficient pool of data for analysis, and will also guarantee a good cross-section of membership. The composition of membership is important because we desire to understand how different user characteristics impact on discourse and behaviour, and consequently, on the value co-creating interactions between members of different status and expertise. Finally, the availability of performance metrics will enable us to more easily codify the role and status of IDS participants. Using the ‘communicative practices framework’ of Campbell and Cecez-Kecmanovic (2011) and the ‘interaction analysis model’ of Gunawardena et al. (1997), we have planned a series of interviews with key stakeholders in the IDS stock trading community to examine the conceptualization and relevance of the constructs and processes depicted in our model (Figure 1). The interviews will provide an opportunity to elicit information on the efficacy of these frameworks, and to observe the decision making models of participants, the

importance of systemic and human factors, and the particular types of information that have the greatest impact on trading behaviour.

Using the findings of the pilot study and the interviews as a guide, we will capture and analyse information within particular threads in the two selected communities over the ten year period from 2001-2012. This period is significant as it will enable us to track and isolate the influence of key external events such as the global financial crises. The content analysis will investigate the flow of communication (in terms of technology moderated speech acts), and how this communication contributes to the construction and sharing of knowledge, and maintenance of social interaction within an IDS. The goal of this analysis is to codify the presence of different communication strategies and the processes by which knowledge is co-created. Preliminary correlation analysis will be used to understand how these sources of collective intelligence impact on different types of trading behaviour, and how they are influenced by the availability of systemic and human factors.

Stage 3: Explanatory Phase (Aim 2)

The data for this stage will be collected via an Internet-based survey with two sections. The first section will require respondents to answer a number of questions that will be used to create a profile of the respondent (i.e., risk orientation, incentive preferences, trading experience etc.). The second section of the survey will present the respondent with a series of choice tasks. Following Van Bommel (2003), we will use scenarios to contextualize the choice tasks. Each scenario will systematically vary the type of communicative practice used, nature of knowledge co-created, regulatory environment, and characteristics of the IDS. Assuming that strong support is observed during the exploratory phase for the dimensions associated with these factors; we would anticipate having 16 scenarios based on resolution 3 fractional factorial design. Each scenario would represent a different version of the survey, with respondents randomly allocated to a survey version.

In each version of the survey, the respondents will be presented with eight choice tasks. In each choice task, respondents will be required to choose the most likely market activity to result from the particular scenario. Each option within the choice task will present three different combinations of price, volume, volatility, arbitrage and market cycles, where the levels of these attributes will also vary based on an underlying experimental design. For each task, the respondents will be asked to answer three related questions: (i) Of the three presented options, which option do you think is more likely to occur? (ii) Of the remaining two options, which is least likely to occur? And (iii) If you were given the choice of choosing one of the three options available or none, which would you choose?

The survey will be conducted online with a sample of stock market traders. The population for the survey will be drawn from a commercially available SPAM-compliant list of individuals who regularly use an IDS, and who have traded online during the preceding 12 month period. A randomly selected list of 1000 individuals will form the sample population for each survey (i.e., 16,000 in total). Based on our prior experience with the use of such methods, we would anticipate a resulting sample size of 100-200 per survey. This sampling strategy will ensure that there are sufficient responses to permit the desired statistical analysis.

To establish the relative importance of each factor, we will first examine whether the parameter estimates (from the conditional logit model) vary among respondents as a function of their communication preferences. However, in order to do this, we first need to ensure that the differences in the associated model parameters are not the result of systematic variance (i.e., scale factor inequivalence). Using the procedures outlined by Swait and Louviere (1993), we will identify a base model, then estimate a multiplier for each of the other models in relation to the base model. We will then test whether the parameters are statistically different across the 16 scenarios using multi-group analysis (Louviere et al. 2000).

While the analysis and comparison of the 16 DCA models will provide some insight into the factors that have the greatest influence of trading behaviour for different communicative practices and knowledge co-creation preferences, if we are to examine the impact of the human factors identified in the first section of the survey, we will need to introduce covariates to analyse for heterogeneity. One way of doing so is to overlay a latent class (finite mixture) model on top of the original logit model to capture some of the unexplained variance in trading behaviour. By introducing covariates we can observe how user characteristics impact on the interaction among the communicative practices, knowledge co-creation and trading behaviour. This analysis will result in the identification of class-level models that will provide a much more detailed picture of the requirements for investment success.

Stage 4: Development Phase (Aim 3)

The translation of the results of Stage 3 into a prototype DSS will be a relatively straight forward process. The DCA analysis conducted in the previous stage, and the resulting conditional logit and latent-class models, will provide information on the relative importance of the various factors in our study. This weighting information

can be used to populate "what-if" analysis to show users how changes in the level of one or more factors can impact the other factors within the model, and also the overall performance of a given stock.

Two different DSS prototypes will be designed. The first will be a web-based interface for use with either a desktop or laptop computer, and the second will be a more compact version for use with a mobile device. In line with the recommendations of information systems design theory (Gregor and Jones 2007), the prototype design process will involve a consideration of the (i) purpose and scope, (ii) principles of form and function, (iii) justificatory knowledge (i.e., supporting theory), and (iv) principles of implementation (i.e., instantiation). Test scenarios for the prototype will draw on historical market data, and will seek to examine the extent to which the DSS can mitigate investment uncertainty and model actual market fluctuations. Automated semantic analysis based on the communication processes codified in stage 3 will be used to identify different communication and knowledge creation patterns within the text posts. These patterns will be used as inputs for the DSS.

While there is an underlying goal to test the efficacy of the system, there is also a need to ensure that the system design facilitates effective use. As such, we need to observe people using the prototype system, and to discover unexpected errors and areas for improvement. The testing will involve a number of waves of measurement. Each wave will examine how well the interface responds in the areas of performance, accuracy, recall, and emotional response; with system modifications between each wave. The results of the first wave will be treated as a baseline/control measurement, with all subsequent waves compared to the baseline to indicate improvement. Specific issues to be examined during the testing phase include:

- *Performance:* How much time, and how many steps are required for people to complete the task?
- *Accuracy:* How many mistakes did people make and were the mistakes fatal or recoverable with the right information?
- *Recall:* How much does the person remember after the testing, or after periods of non-use?
- *Emotional response:* How does the person feel about the tasks completed? Are they confident? Would the user be willing to participate in future testing?

Based on the recommendations of Virzi (1992) each test will involve 10 users, with the total number of waves to be determined when no further improvements can be made. This recommendation is based on the observation that the probability of identifying an actual problem increases with the number of participating users up to about 10 persons, with the benefit of additional participants deemed marginal beyond this number.

CONCLUSION

Financial IDS have the potential to both positively and negatively influence the efficient operation of capital markets. On the positive side, these sites provide a venue for real-time interpretation of publicly available information that can enhance market efficiency. On the downside, these sites increase noise in capital markets, creating false markets and providing competing venues for the disclosure of private information. Continuous monitoring of these sites by regulators is virtually impossible at present due to the volume of information and the limited resources available to regulators.

IDS communities are a microcosm of the financial markets' information environment. Using the activity and content of the posts on these sites allows us to directly observe how a subset of the investment community interprets and responds to information and noise posted on these sites. These observations also occur within the context of other information releases (outside of the IDS) and financial market activity. This provides an opportunity to directly observe how participants both individually, and collectively, respond to and utilize the information associated with these events. Despite the potential of IDS-based communication to enhance market efficiency, the interaction processes within financial IDS communities, and the information generated by participants, remain largely unexplored. We also know little about how participants establish social interaction and share knowledge, or what characterizes their communication behaviours, how this impacts on participants' engagement with an IDS, and their subsequent trading behaviour.

This research project will focus on the development of a DSS tool for modelling the complexity of IDS-related content and communication processes. A four stage, sequential mixed methods approach will be used to develop the DSS. The first stage is completed and has demonstrated the value of communicative practices as a correlate of trading activity. The second stage will examine how various systemic and human factors impact communicative practices and information sharing. In the third stage it is proposed to examine the interaction between model factors, and how they may impact investment decisions. The fourth and final stage will use combinatorial model outputs to inform the development of a DSS tool.

The resulting tool will inform investment decision making by synthesizing collective market intelligence through automated semantic analysis, and assist investors to conduct "what-if" analysis using this information and the

weightings of the DCA work. Because of its focus on communicative practices, this tool will also help identify manipulative communication behaviours which will be of value to IDS administrators and enable market regulators to identify instances where legal or other types of intervention may be required. This system will therefore offer significant economic benefits through better informed and regulated asset markets.

REFERENCES

Antweiler, W. and Frank, M. 2004. "Is all that talk just noise? The information content of Internet Stock Message Boards," *Journal of Finance* (59). pp 1259–1294.

Campbell, J. and Cecez-Kecmanovic, D. 2011. "Communicative Practice in an Online Financial Forum during Abnormal Stock Market Behavior," *Information & Management* (48:1), pp 37-52.

Campbell, J., Fletcher, G. and Greenhill, A. 2009. "Conflict and Identity Shape Shifting in an Online Financial Community," *Information Systems Journal* (19:5), pp 461–478.

Campbell, J.A. 2001. "In and Out Scream and Shout: An Internet Conversation about Stock Price Manipulation," in Ralph H. Sprague Jr. (ed.) *Proceedings of the Thirty-Fourth Annual Hawaii International Conference on System Sciences*, IEEE Computer Society Press, Maui Hawaii USA, 3-6 January, ISBN 0-7695-0981-9, pp 1-10.

Choi, J.J., Laibson, D. and Metrick, A. 2002. "How does the Internet affect trading? Evidence from investor behaviour in 401(k) plans," *Journal of Financial Economics* (64:3), pp 397-421.

Cowan, N., Chen, Z. and Rouder, J.N. 2004. "Constant Capacity in an Immediate Serial-Recall Task: A Logical Sequel to Miller (1956)," *Psychological Science* (15:9), pp 634-640.

Clarkson, P.M. , Joyce, D. and Tutticcia, I. 2006. "Market reaction to takeover rumour in Internet discussion sites," *Accounting and Finance* (46:1), pp 31-52.

Fama, E.F., Fisher, L., Jensen, M. and Roll, R. 1969. "The adjustment of stock prices to new information," *International Economic Review* (10), pp 1-21.

Frederick, S. 2002. "Automated Choice Heuristics," in Gilovich, T., Griffin, D., Kahneman, D. (eds.). *Heuristics and Biases: The Psychology of Intuitive Judgment*, New York, NY: Cambridge University Press, pp 548-558.

Gregor, S., and Jones, D. 2007. "The Anatomy of a Design Theory," *Journal of the Association for Information Systems* (8:5), pp 313-335.

Gu, B., Konona, P., Rajagopalan, B. and Chen, H.M. 2007. "Competition among virtual communities and user valuation: The case of investing-related communities," *Information Systems Research* (18:1), pp 68-85.

Gunawardena, C., Lowe, C. and Anderson, T. 1997. "Analysis of a Global Online Debate and the Development of an Interaction Analysis Model for Examining Social Construction of Knowledge in Computer Conferencing," *Journal of Educational Computing Research*, (17:4), pp 307-431.

Henri, F. 1992. "Computer Conferencing and Content Analysis," in *Collaborative Learning through Computer Conferencing: The Najaden Papers,* in Kaye, A. (ed.), Springer-Verlag, Berlin, pp 117-136.

Kahneman, D. and Tversky, A. 1979. "Prospect Theory: An Analysis of Decision Under Risk," *Econometrica* (47:2), pp 263 – 291

Kyle, A., 1985. "Continuous auctions and insider trading," *Econometrica* (53), pp 1315-1335.

Louviere, J., Hensher, D. and Swait, J. 2000. *Stated choice methods: Analysis and applications*, Cambridge University Press, UK.

Lu, Y., Li, L., Dong, D. and Yang, D. 2010. "Is there Two-Way Information Transmission between Stock Markets and Stock Discussion Boards?" *International Conference on Information Systems ICIS 2010*, Paper 35. http://aisel.aisnet.org/icis2010_submissions/35.

Malone, T. W., Laubacher, R. and Dellarocas, C. 2010. "The Collective Intelligence Genome," *MIT Sloan Management Review* (51:3), pp 21-31.

Swait, J., and Louviere, J. (1993) The role of the scale parameter in the estimation and comparison of logit models, *Journal of Marketing Research,* (30:3), pp 305-314.

Teschner, F. and Weinhardt, C. 2012. "Identifying Experts in Virtual Forecasting Communities," *AMCIS 2012 Proceedings*. Paper 4. http://aisel.aisnet.org/amcis2012/proceedings/VirtualCommunities/4.

Tumarkin, R. and Whitelaw, R.F. 2001. "News or noise? Internet postings and stock prices," *Financial Analysts Journal* (57:3), pp 41-51.

Van Bommel, J. 2003. "Rumours," *The Journal of Finance* (58), pp 1499-1519.

Virzi, R. 1992. "Refining the Test Phase of Usability Evaluation: How Many Subjects Is Enough?," *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 34(4), pp 457-468.

Zhang, H., Horvitz, E., Miller, R.C. and Parkes, D.C. 2011. "Crowdsourcing General Market Mechanisms and their Applications," *CHI 2011*, May 7–12, Vancouver, BC, Canada.

COPYRIGHT