A Framework for the System Dynamics (SD) Modeling of the Mobile Commerce Market

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EXTENDED ABSTRACT

Mobile commerce can be simply defined as conducting business activities over mobile terminals. It is the combination of electronic and mobile commerce performed over mobile terminals such as mobile phones, laptops, portable digital assistants (PDA), etc. Typical services include mobile banking, mobile shopping, mobile stock trading, mobile auction etc. It is widely regarded as an important innovation in creating more business opportunities and has a brighter future than its precedent – electronic commerce.

With the development of mobile commerce, a new market of mobile commerce and its derivatives, such as mobile commerce terminal market, mobile network market, mobile equipment market, and mobile software market, comes into existence. However, since mobile commerce is still in its beginning there is a lot of uncertainty in its future. This uncertainty causes the emerging mobile commerce market to be in a dynamic and complicated state.

How to develop a reliable model to explore this new market and examine the behavior of the market development is becoming increasingly important. This paper provides a framework which is practical in building confidence, namely the System Dynamics (SD) modeling of a mobile commerce market. System Dynamics modeling is a rigorous method for studying and managing complex systems. This framework is designed to enhance the model's reliability by combining some group process techniques, like workshops, group discussions, brainstorming, Delphi surveys, and fieldwork, with System Dynamics modeling. The mobile commerce market in this paper is regarded as a social economic system. The model-building process makes full use of group techniques so that the model can reasonably incorporate a wide variety of sources of knowledge including: system thinking, system dynamics, management science, mobile commerce, and marketing and hence the reliability is enhanced. The framework covers three stages of the model-building process: modeling, testing, and experimenting.

In the modeling stage, the framework is aimed at developing a mental representation, identifying the Causal Loop Diagram (CLD) and the Stock Flow Diagram (SFD), with which a simulation model can be developed for the mobile commerce market. A CLD links variables that have causal interpretation and an SFD represents the structure of a target system with denotations of accumulation and flow rate. In this stage, mental representations are drawn in workshops attended by a group of researchers who elicit knowledge from experts by soliciting their judgments. Casual loop and stock flow diagrams are next developed and relationships between the variables are formalized using mathematical, logical and theoretical means and expert's opinion are solicited for justifying the models.

In the testing stage, the aim is to test the robustness of the model developed. In addition to passing some common sense tests, the model has to pass several specific tests on some key parameters determined by the panel of researchers in order to examine the fitness of the model by comparing historical data with simulation results data. In the experimenting stage, the model is simulated to analyze the behavior of mobile commerce diffusion under different scenarios of national planning policies. As an illustration, a simulation model is empirically developed, calibrated and simulated for the Chinese market.

In general, we found the framework to be useful for modeling mobile commerce diffusion in the Chinese mobile commerce market formation example.

1. INTRODUCTION

Everyday we face decision-making issues. Static, one-factor, short-term problems regarding one discipline are increasingly replaced by dynamic, long-term, real-time, multifactor, interdisciplinary problems. This phenomenon requires researchers to have a system thinking view (Jackson, 2003, Wolstenholme, 1994) and solve the problems by making full use of contemporary modeling methods and powerful computer simulation techniques. Modeling and simulation have been widely used in the natural and social sciences. However, literature and experience tell that modeling, especially in the social sciences, will meet trust issues. Modelers often use different methods and theories in practice, and no two modelers can develop the same model for a system. Therefore authority proclaims, "All decisions are based on models… and all models are wrong" (Sterman, 2002). Does it mean the practitioners have to totally negate the applicability of modeling in social science? The answer is negative. "All models are wrong but some are useful" (Box, 1979). Despite that, behind the story of any model may lie a story about the analysts and the process that created it (Kimberly and Thompson, 2005). The key point is how to select appropriate methods that can elicit more knowledge in order to build reliability and confidence during the process of modeling a social issue.

System Dynamics simulation modeling (Sterman, 2000) is a rigorous modeling method that enables users to build formal computer simulations of complex systems and use them to design more effective policies. System Dynamics was first created by Jay Forester (1961, 1969, 1973). It involves a mental representation of a system, causal loop diagramming, stock and flow diagramming, formal modeling, testing, and experimenting. This paper provides a multi-methods knowledge-eliciting framework for System Dynamics modeling of the mobile commerce market.

Mobile commerce is defined as conducting business activities over mobile terminals (such as mobile phones). Exploring an emerging mobile commerce market and examining its development behavior is a typical social economic issue. In exploring a new market, all processes are of primary concern. If more knowledge is elicited in the processes of modeling, the reflection of the real world will become more reliable and persuasive. Since the behavior and structure of the simulation can be used for forecasting the behavior and structure of a real world system, the focus is therefore on how to use ordinary methods in soliciting as much knowledge as possible in order to build a reliable simulation model.

In our framework, we try to use practical methods, like group research, workshops, brainstorming, Delphi survey, and fieldwork for this purpose. The modeling process starts by establishing a research group, and identifying the mental representations using workshops and Delphi surveys. Next a Causal Loop Diagram (CLD) and a Stock Flow Diagram (SFD) are drawn and a simulation model is developed using group analysis and the Delphi technique. As an illustration, a simulation model is calibrated and then simulated to examine the behavior of the Chinese mobile commerce market. We used our framework to provide a practical example of using the System Dynamics approach to model mobile commerce development.

The rest of this paper is organized as follows. The next section describes the framework in general. Then follows an illustration of the methods embedded in the processes and finally a list of findings that are drawn from the implementation of this framework in the modeling of mobile commerce market formation in China is presented.

2. AN SD MODELING FRAMEWORK

System Dynamics deals with the time-dependent behavior of systems with the aim of describing the system and understanding, through qualitative and quantitative models, how information feedback governs its behavior, and designing robust information feedback structures and control policies through simulation and optimization (Coyle, 1996). As illustrated in Figure 1, it includes the causal loop diagramming, stock flow diagramming, formalizing, and experimentation.

Causal loop diagramming is the first key result that is generated from the framework. It links the variables that have causal interpretation. It synthesizes all the mental representations of a target system. Stock flow diagramming is the second key result out of the framework. It represents the structure of a target system with denotations of accumulation and flow rate. A stock flow diagram contains the building blocks of a simulation model. In the next sections we explain the 11-step process we used for creating the SD model, testing and experimenting with it.

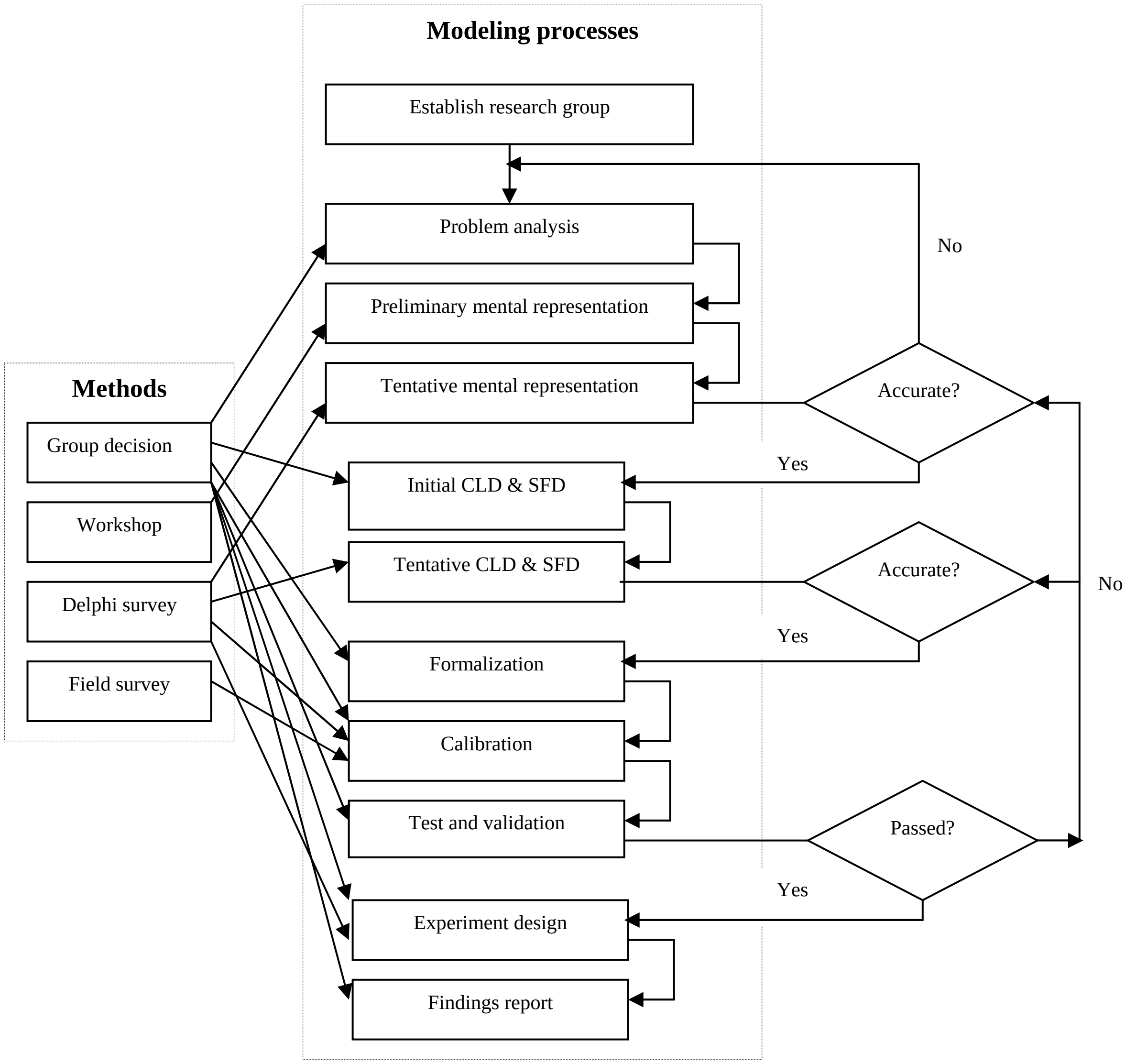

Figure 1. Framework for SD modeling

2.1. Step one: Set up a research panel

When a project is started, a research panel is established. The participants should be of diverse background and should easily communicate with each other. For example, the composition of a research group of 5 members set up for modeling mobile commerce is as follows: one mobile commerce professional, one mobile commerce marketer, one experienced SD modeler, one market analyst from a consultant company and one representative from an enterprise. In addition, one of the members from the research group acts as an administrator in charge of administrative work, such as organizing discussions, disseminating information, and analyzing data. When the research group is in existence, a detailed schedule of tasks are planned to guide in the right direction.

2.2. Step two: Problem analysis

Using the specifications of the project, the panel will define the research questions in order to determine the boundary of the system. We used a qualitative question to describe the project. This descriptive question is then broken down into several investigative sub-questions. The scope of the questions will help decide on the boundary of the target system or subsystems. The main method employed in this step is several rounds of group discussions within the panel. In our research, the purpose is to develop a model that can be used to explore the formation of the mobile commerce market in a country, assuming that mobile commerce will soon be adopted in the country. The project will focus on examining the processes within a national system that might contribute to the mobile commerce market formation. Particularly, the influential endogenous factors that will be identified might provide policy makers and planners with clues on how to understand mobile commerce diffusion in the future. This perspective forms the basis for this research. Our problem definition for building the model is "How mobile commerce users will develop in an market in general?"

2.3. Step three: Preliminary mental representation

This is a very important step in conceptualizing SD modeling (Randers, 1980, Forrester, 1992). The purpose of this step is to form a preliminary general overview of the components in the system and their dynamic interrelationship. This step includes an analysis of the boundary and identification of the state factors involved in the process of mobile commerce market formation. The method used in this step is brainstorming within the panel and workshops with an enlarged group.

Brainstorming within the panel generates the primitive mental representation from the panel, from which will be derived guidelines for conducting workshops in an enlarged group. Workshops are conducted afterwards. The participants in the workshops should be diversified in their age, work experience, career, education, origin, etc. The number of the participants depends on the requirements and budgeting of the project and is determined by the research group. In each workshop, a diagram illustrating the system boundary and the state variables involved is drawn for analysis. The panel should synthesize the mental representations from all the workshops and draw a picture depicting the boundary and the state factors. In our research, the boundary is a mobile commerce market in a geographic region under a country's jurisdiction. The main state factors include people, mobile phone users, PDA users, laptop users, mobile commerce terminal users, etc.

2.4. Step four: Tentative mental representation

A mental representation of the project is then further enhanced through a Delphi survey. A questionnaire that illustrates the mental representation is disseminated among the selected experts. The number of experts is 8-12. The experts are carefully chosen with diversified background. For modeling the mobile commerce market, it is desirable to have 8 experts plus 3 substitutes selected from academy, government, enterprise, and media act as permanent judgmental group. After several rounds of questionnaire surveys, a consensus can be reached and stored as an optimal option of the mental representation of the system. However, this does not mean that it is the end of the process of mentally representing the system. Since the whole process is iterative, this mental representation will be used as a temporary footstone to the next step. The applicability and compatibility of the mental representation within the process will be constantly checked and adjusted in the next steps.

2.5. Step six: Initial CLD and SFD

The factors included in the mental representation can be classified into four categories: state variables, rate variables, auxiliary variables, and isolated ones. A state variable determines the state of the system at a point in time. A rate variable will change a state variable. An auxiliary variable provides information to state and rate variables. An isolated variable is one that has no connections with other factors. It can be temporarily put aside. Whether the isolated variables are discarded or not should be further determined after more iteration and simulation. As done in the step of preliminary mental representation, each member of the research group will independently classify the variables and draw their own CLD and SFD. A discussion is then organized among the group to reach agreement on the initial CLD and SFD.

2.6. Step seven: Tentative CLD & SFD

In this step, the research group will interpret the initial CLD and SFD as questions in a questionnaire and then organize a Delphi survey. As in step four, a Delphi survey is prepared and conducted in this step. Questionnaires that describe the initial CLD and SFD are designed and disseminated among the same group of experts. This survey can be simultaneously performed in combination within other Delphi surveys in this research. After a consensus is reached, the group will interpret the result back into a tentative CLD and SFD.

2.7. Step nine: Formalization

Formalization is aimed at establishing the theoretical, logical, mathematical relationships between variables that appears in the CLD and SFD. The key points in this step are the selection of applicable theories, the modification of existing theories, and the development of new theories. First, the research group will examine the relationships between state variables and any existing archetypes and theories that are applicable. If there is no archetype or theory, the group has to develop its own theories after interviewing experts in the relevant discipline.

Then the group will literally translate the archetypes and theories used into questionnaires and conduct the Delphi survey as explained in steps 4 and 7.

2.8. Step nine: Calibration

There could be hundreds of parameters in a middle-sized model. All the parameters should be calibrated before the model can be further tested. Parameters can be classified into sensitive ones and non-sensitive ones. The values or the range of values of non-sensitive parameters can be arrived at by common sense or judgment because of their non-sensitivity. Sensitive parameters are further divided into available parameters and unavailable parameters. The values or the range of values of the available parameters can be directly obtained from secondary data sources such as databases, archives, or previous research. Unavailable parameters can be further divided into judgmental parameters and formal parameters. The values or the range of values of the judgmental parameters are determined by a Delphi survey. The value or the value ranges of the formal parameters are obtained through fieldwork data collection.

2.9. Step ten: Testing and validation

After the model has been formalized and calibrated, the model is ready for testing. Testing is performed among the research group. First, the group will establish a test plan, which specifies test cases, methods, and results. Then, each member, as an examiner, will independently conduct a series of tests. Each examiner will provide a test report, all test reports are synthesized and evaluated, and a decision is made as to whether testing was successful or not. If testing is unsuccessful, the cause of the problem must be identified and the model modified and further tested. This is an iterative process and is conducted until testing is successful.

2.10. Step eleven: Experimentation

If the testing is successful, the model is ready for experimentation. First, the group designs an experiment plan, which specifies the purpose, and outcomes of the experiment. Then, each member of the group independently implements his or her experiments and writes an experiment report. In the report, experimenters will list the procedures and parameters used, and record the phenomena and findings for each experiment. Afterwards all the reports are collected and distributed among the group members for analysis. The group will reach a common opinion in interpreting the phenomenon, determine whether the findings are significant, and write a finding report.

3. RESULTS AND FINDINGS

In a previous work (Wang and Cheong, 2004, Wang and Cheong, 2005a,b), we used this framework for examining the formation of the mobile commerce market in China. Our findings in using the framework are presented in the next sub-sections.

3.1. Causal loop diagram

Figure 2 is the causal loop diagram (CLD) for a mobile commerce market. The market is regarded as a system. In this system, there is a certain amount of population. From this population, there is a certain amount of capable population, who has the capability to use mobile terminals. From the capable population, there are a certain number of mobile terminal users, who have already bought their mobile terminals. From these mobile terminal

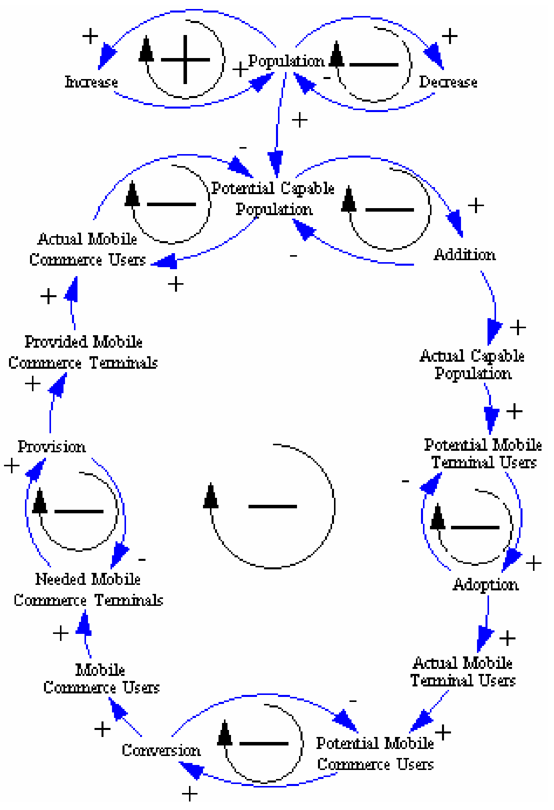

Figure 2. Causal Loop Diagram

users, there are a certain number of potential mobile commerce users, who want to accept the mobile commerce services. However, only mobile commerce terminals can provide mobile commerce service to the potential users, so manufacturers of these devices start to produce and provide this kind of terminal to the market. Then, when users get this kind of terminal, the potential mobile commerce users become the actual mobile commerce users.

3.2. Stock flow diagram

Figure 3 is the stock flow diagram (SFD) for the system. The formation of the mobile commerce market is like a water irrigation system. The population is the source at the top. The flow starts at the population level, passing downstream to the lower levels. In the process, the flow is adjusted by the valves in the system and changes the value of the levels of the stocks. Each level in this diagram can be regarded as a subsystem and can be developed as a sub-model.

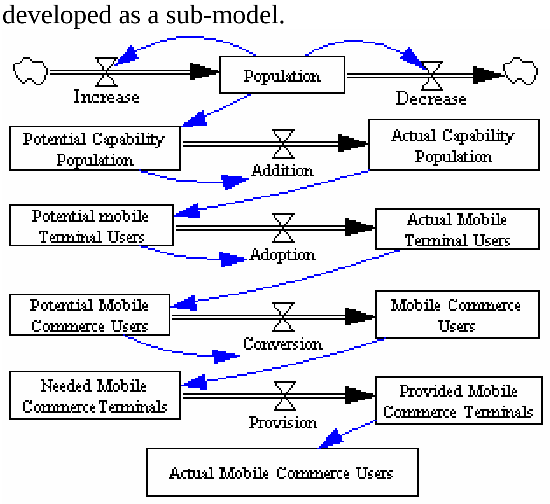

Figure 3. Stock Flow Diagram

3.3. Influential factors

In our simulation we found that the population policy, urbanization policy, market openness policy, education, and strategic planning of the mobile commerce terminal (MCT) industry would have a profound influence on the formation of mobile commerce market. They are the key state factors that form the foundation on which the current state and future perspectives of the mobile commerce market is based.

3.4. Scenario design

We found that the MCT strategic planning was one of the most uncertain factors in the system. Therefore an appropriate scenario design should be the combination of a basic state, which is the set of parameters and equations, with different MCT strategic planning. A list of the elements used for determining the basic state of the mobile commerce market and the MCT strategic planning in China is shown next.

Factors used:
CN (t) =child number of a couple (persons/couple)
AG (t) =age at which a couple has first child (years)
UF (t) =urbanization fraction (%)
FIP (t) =fraction of illiterate people (%)
FTP (t) =fraction of tertiary educated people (%)
MMO (t) =mobile commerce market openness (%)
MC (t) =MCT capacity (units/year)
STEP (t) =years
Parameters and equations identified for basic state:
CN (t) =1.5, t= [0, 10]; CN (t) =2, t= (10, +∞)
AG (t) =25, t= [0, 10]; AG (t) =22, t= (10, +∞)
UF (t) =RAMP (70/20, 0) when t= [0, 20]
UF (t) = 70 when t= (20, +∞)
FIP (t) =1-RAMP (10/10, 0) when t= [0, 10]
FIP (t) =0 when t= (10, +∞)
FTP (t) = RAMP (60/20, 20) when t= [0, 20]
FTP (t) = 60 when t= (20, +∞)
MMO (t) =20+RAMP [(49-20)/5, 5] when t= [0, 5]
MMO (t) =49 when t= (5, +∞)
Positive MCT strategic planning:
MC (t) =RAMP (10^7/15, 0) when t= [0, 15]
MC (t) =10^7+RAMP [($1.5*10^8$- 10^7)/12, 15] when t= (15, 27)
MC (t) = $1.5*10^8$ when t= [27, +∞]
Negative MCT strategic planning:
MC (t) =RAMP ($5*10^6$/15, 0) when t= [0, 15]
MC (t) =$5*10^6$ +RAMP [($1.5*10^8$-$5*10^6$)/12, 15] when t= (15, 27)
MC (t) =$1.5*10^8$ when t= [27, +∞]

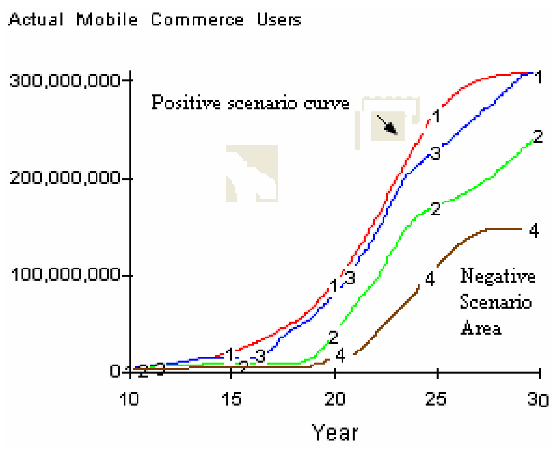

Figure 4. Mobile commerce market formation

3.5. Behavior analysis

A positive scenario and a negative scenario can be obtained by combining the basic state with two types of the MCT strategic planning. Figure 4 illustrates the behaviors of the mobile commerce market under the two scenarios. Under the positive scenario, as shown by plot line 1, the mobile commerce market formation will always follow this standard s-shaped curve. It takes about three decades for the market to reach equilibrium at three hundred million of mobile commerce users. Under the negative scenario, as shown in plot lines 2, 3, and 4, the mobile commerce market formation will be more or less constrained by the bottleneck from the MCT industry. It takes the same behavior as the mobile commerce terminal provision. The entire mobile commerce market behavior curves will fall into the negative scenario area, which is underneath the plot line 1.

4. CONCLUSIONS

The aim of developing an iterative multi-method knowledge-eliciting framework is to build confidence and enhance the reliability in the practice of System Dynamics modeling of a social economic system. The methods embedded in the modeling process are practical for eliciting wider knowledge.

The implementation of the framework in the System Dynamics modeling of the mobile commerce market development in China shows the population policy, urbanization policy, market openness, education policy, and the strategic planning of mobile commerce terminal industry will significantly influence the formation of the mobile commerce market.

Based on the influential factors, we designed two typical scenarios and we analyzed the behavior of the model. We found that: 1. under the positive scenario, mobile commerce market formation will take an S-shaped behavior in general; the mobile commerce will obtain an optimal development; 2. under the negative scenario, the MCT strategic planning will constrain the free formation of the mobile commerce market. Appropriate adjustment of these involved influential factors combination will lead to the development of the mobile commerce market in the expected direction.

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