

# A Culture-Sensitive Agent in Kirman's Ant Model

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**Abstract.** The global financial crisis brought a serious collapse involving a “systemic” meltdown. Internet technology and globalization have increased the chances for interaction between countries and people. The global economy has become more complex than ever before. Mark Buchanan [12] indicated that agent-based computer models will prevent another financial crisis and has been particularly influential in contributing insights. There are two reasons why culture-sensitive agent on the financial market has become so important. Therefore, the aim of this article is to establish a culture-sensitive agent and forecast the process of change regarding herding behavior in the financial market. We based our study on the Kirman's Ant Model[4,5] and Hofstede's Natational Culture[11] to establish our culture-sensitive agent based model. Kirman's Ant Model is quite famous and describes financial market herding behavior from the expectations of the future of financial investors. Hofstede's cultural consequence used the staff of IBM in 72 different countries to understand the cultural difference. As a result, this paper focuses on one of the five dimensions of culture from Hofstede: individualism versus collectivism and creates a culture-sensitive agent and predicts the process of change regarding herding behavior in the financial market. To conclude, this study will be of importance in explaining the herding behavior with cultural factors, as well as in providing researchers with a clearer understanding of how herding beliefs of people about different cultures relate to their finance market strategies.

**Keywords:** Culture, national culture, simulation, agent-based model, herding, conformity.

## 1 Introduction

The global financial crisis started in 2007 and occurred according the “Butterfly Effect” bringing serious collapse similar to a “systemic” meltdown. The crisis affected all financial markets and the entire global economy. We cannot imagine the full scope or degree of the impact. Mark Buchanan [12] suggested that agent-based computer models will prevent another financial crisis and he has been particularly influential in contributing insights. Conversely, as internet technology and globalization increase, so

does the interaction among countries. Additionally people and culture bring more variation and dissimilarity. In the past, numerous studies have attempted to explain culture, but studies of embedded agent-based models are still few. For those reason affecting the new global economy, designing a culture-sensitive agent-based model has become a central issue for financial markets. Consequently, we expect to establish a culture-sensitive agent and observe or forecast the process of change regarding herding behavior in financial markets.

The word “culture” most commonly consists of the knowledge, belief, attitudes, values, and behavior that are related to the ability for representative thinking and social learning. Culture influences the way people make decisions and performs actions. Cultural dissemination or acculturation is influenced by both external and internal factors from people, society, business, or country. Examples of external factors are new societies and technology, while internal factors are the powers of encouraging and resisting social structures and natural events. When one culture faces new ideas or events, it decides whether to accept or reject it. The phenomenon of culture change will be preceded. Therefore, culture has a significant influence on individuals, business, society, and country.

The global financial crisis of 2007 began from a liquidity deficit in the United States banking system that had a tremendous effect on society. It should be noted that herding behavior (also called conformity) also expanded the extent of the hazards caused by the financial crisis. Herding behavior describes different human behavior in various countries. Different countries have various norms regarding their cultures. The phenomenon of herding behavior in different cultures is affected by various norms. In research on culture and herding behavior, Asch [1,2] investigated the relationship between herding behavior and culture based on individualism-collectivism. The herding behavior is determined by goals of individual and is a significantly affected by cultural. Based on obedience experiments, Stanley Milgram [3] proved that Norway engages in more herding behavior than France does, confirming the existence of culturally different factors affecting herding behavior.

There has been a significant growth in research regarding agent based simulation in recent decades. In herding behavior of agents, Kirman’s model[4,5] established herding behavior (also called conformity) in aggregate expectations stimulating agent interactions. The phenomenon of model is more psychologically driven than economically driven. This herding mechanism was inspired by an observation in entomology. “Ants, faced with two identical food sources, were observed to concentrate more on one of these, but after a period they would turn their attention to the other.” Inspired by observing the behavior of ants, Kirman characterized the swinging potential of each individual by two parameters, namely, a probability of self-conversion and a probability of being converted. The self-conversion probability raises the probability that an individual will change to other types of agents without external influence, while the probability of being converted increases the probability that the individual will be influenced by other individuals. This changing process is discrete and can be deliberated in a general theoretical framework of a Polya urn process [13] (N-path dependence).

Culture-sensitive agent models have focused on the interactions of individuals from different cultures. The Axelrod [6] model presents a viewpoint of formal cultural dissemination. Axelrod used cellular automata techniques to simulate individual communication and interplay regarding each other’s belief in local networks when they have similar traits. The traits of all the individuals could directly converge to new a

culture. Individuals were affected by society. Therefore, Axelrod’s model is understood to be a formalized form of culture. A formal culture can be defined apart from any diffusion and the changing rules involved. This is conducted by designating a set of mathematical symbols and a set of formation rules that determine which mathematical symbols are well-formed formulas. When transformation rules (also called rules of inference) are fired, and certain traits are accepted as axioms (together called a deductive system or a deductive apparatus), a logical system is formed. A new culture is created and influenced by these firing rules. Therefore, the rules of logic depend upon their traits.

According to the Axelrod definition, behavior of individuals is followed by a certain pattern, and if individuals detach from this model they are subject to a penalty. The individual’s behavior pattern is affected by the culture of society.

Furthermore, Geert Hofstede’s five dimensions of culture have been used to describe cultural differences. Recently, Geert Hofstede, Gert Jan Hofstede, Catholijn Jonker and Tim Verwaart had incorporated four of these five dimensions into an agent-based model of trade negotiation. The four dimensions are power distance [7], individualism [8], uncertainty avoidance [9], and long-term orientation [10].

To what extent does culture have influence on herding behavior? How do different countries with diverse cultural norms cope with herding behavior? In this paper, we present herding behavior regarding culture in four scenarios: Eastern culture, Western culture, confliction, and fusion. We combined Kirman’s Ant Model of herding behavior and one of the five dimensions in Hofstede’s model of national culture, individualism, and collectivism. We formulated rules of culture and herding behavior to discuss how and why herding behavior is embedded in different cultures.

## 2 The Model

The culture-sensitive Kirman’s Ant Model consists of two parts: culture-sensitive and herding behavior. In the culture-sensitive part, we focus on individualism and collectivism aspects of Hofstede’s cultural consequences [11]. National culture has some distinctions between norms in collectivist and individualist societies, as shown in Table 1. Individualist societies are loose and most individuals look out for himself or

**Table 1.** Distinctions between norms in collectivist and individualist societies

<b>Collectivist</b>	<b>Individualist</b>
Maintain harmony, avoid confrontation	Speak your mind
High-context, implicit communication	Low-context, explicit communication
Use the word "we"	Use the word "I"
Show favor to in-group customers	Treat all customers equally
No business without a personal relation	Task is more important than a good relation
A relation brings rights and obligations	Mutual advantage is the basis of relations
Relations are given	Build and maintain relations actively
Save face for in-group	Keep self-respect
Responsible for group interests	Responsible for personal interests
Source : Hofstede [11].	

herself. Whereas the collectivist society integrates into cohesive groups and protection is exchanged for loyalty. Asch [1,2] proved that agents increase herding behaviors from collectivist societies and decrease from individualist societies.

However, Hofstede [11] examined numerous different cultures on individualism and collectivism dimension (IDV). China, Hong Kong, Singapore, and Taiwan have lower IDV value; their cultures are called Eastern culture. Australia, Canada, United Kingdom, and United States have higher IDV value, are called Western culture, as shown in Table 2.

**Table 2.** Individualism and Collectivism Dimension Value

Eastern Country	IDV	Western Country	IDV
China *	20	Australia	90
Japan	46	Canada	80
South Korea	18	United Kingdom	89
Hong Kong	25	United States	91
Singapore	20	Germany	67
Taiwan	17	Sweden	71

Source : Hofstede[11].

Conversely, Kirman applied ant behavior, also known as the urn process path [13] (N-path dependence), to explain the phenomenon of herding and epidemics, similar to the stock market. The model was an entomologist’s experiments. The ants of model faced with two food sources: black and white state of the system. The observation concentrated one of the states, after a period they would change their mind to the others[4].

This system had two dynamic parameters ( $\delta, \epsilon$ ), converting rate, and self-converting rate. The Converting Rate ( $1-\delta$ ) determines the probability of the first ant and the second ant meeting. The Self-Converting Rate ( $\epsilon$ ) decides the probability of the first ant changing its color independently before meeting the other ant.

This paper combines the cultural parameter (I) of individualism and collectivism and Kirman’s ant model as a culture-sensitive agent. We report the observation of how culture affects herding behavior. The switching rate of the modified Kirman’s Ant Model is as follows.

**(1) k to k+1 with probability**

$$p_1 = P(k, k - 1) = \left(1 - \frac{k}{N}\right) \left(\epsilon + (1 - \delta - I) \frac{k}{N - 1}\right) \tag{1}$$

**(2) k to k-1 with probability**

$$p_2 = P(k, k - 1) = \left(\frac{k}{N}\right) \left(\epsilon + (1 - \delta - I) \frac{N - k}{N - 1}\right) \tag{2}$$

The algorithm is shown in Figure 1.

- Step 1. Randomly initialize ant's position on black or white.
- Step 2. Is the algorithm enough stop criteria? If it is enough then stop run.
- Step 3. Self-Converting Rate Rule  
Select first ant and use self-converting rate ( $\epsilon$ ) to determine if the ant can convert by itself.
- Step 4. Converting Rate Rule  
Select first ant and second ant, then use converting rate:  $(1-\delta-I)$  to determine if the first ant can convert.
- Step 5. Calculate black ants of next state  
applying a probabilistic state transition rule to calculate equilibrium distribution,  $K/N$ , and frequency.
- Step 6. The model stops at its criteria, if not it will go back to Step 3.

**Fig. 1.** Algorithm of culture-sensitive Kirman's ant model

### 3 Experiment Result

Our simulation was based on the uniform distribution of Kirman's Ant Model with converting rate  $(1-\delta, \delta=0.02)$  and self-converting rate  $(\epsilon, \epsilon=0.01)$ . The cultural ingredient affected on delta value ( $\delta$ ) and converting rate  $(1-\delta)$  according to previous investigation. We then fixed the number of agents at  $N=100$  and ran 100,000 times in six scenarios with different initial conditions.

Case 0: No Cultural Factor

Initial condition: 100 individuals put on black and white source randomly.

Case 1: Eastern Culture

Initial condition: 100 Eastern individuals put on black and white source randomly.

Case 2: Western Culture

Initial condition: 100 Western individuals put on black and white source randomly.

Case 3: Cultural Conflict

(1) Initial condition: 50 Eastern individuals put on black source and 50 Western individuals put on white source.

(2) Initial condition: 50 Western individuals put on black source and 50 Eastern individuals put on white source.

Case 4: Cultural Fusion

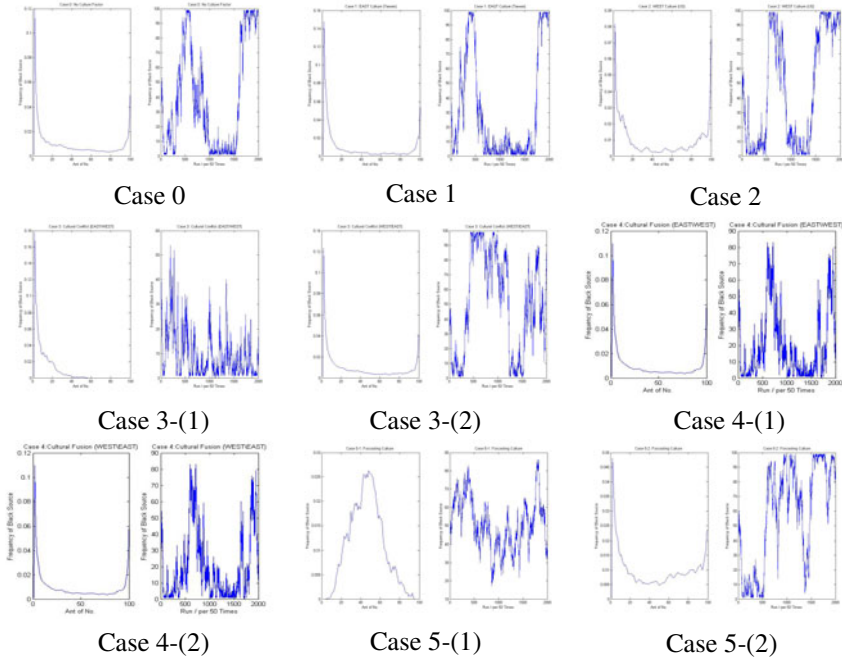
(1) Initial condition: 50 Eastern individuals put on black source and 50 Western individuals put on white source.

(2) Initial condition: 50 Western individuals put on black source and 50 Eastern individuals put on white source.

The first ant change cultural ingredient ( $\delta$ ) when meet the second ant. The new cultural ingredient ( $\delta$ ) of the first ant will be equal to the average of the first cultural ingredient ( $\delta_1$ ) and the second cultural ingredient ( $\delta_2$ ).

Case 5: Forecasting Culture

Initial condition: 100 individuals with random cultural factor put on black and white source randomly.



**Fig. 2.** The simulation results

The simulation results are illustrated in Figure 2. In Figure 2, Case 0 is a non-culture-sensitive factor of herding behavior and is an original Kirman’s Ant Model. In Case 1 and Case 2, the ants have only one pure culture (Eastern or Western). We compared Case 0, Case 1, and Case 2 and determined the culture of individuals increasing the economic situation of optimism and pessimism.

Case 1 refers to the Eastern society and its collectivist cultural context. The individuals are affected by groups in herding behavior. This society has consciousness that is more consistent and sticks on a black or white source for a long time. If the economic environment is not favorable, the individuals are more pessimistic. If they want to become optimistic, they must spend more time to influence each other. Because they have a strong sense of collective consciousness and do not easily break, and vice versa. Hence, government financial policies probably apply a long-term and powerful policy to manipulate investor views. Case 2 refers to the Western society and its individualist cultural context. The individuals exhibit strong minds and diverse beliefs. This society fluctuates and swings on a black or white source quickly. If the economic environment is terrible, the investors are pessimistic at the start. After a period, they will have dissimilar opinions on the economic situation. The individuals contain the differences from cognitive and on the consciousness wandering between optimism and pessimism. They have a strong sense of individual and easily break, and vice versa. Therefore, the financial policies of government may use a fast and dynamic policy to persuade investor views. In Case 3, we considered the experimental case of cultural conflict. A society has two different cultures, and do not completely accept each other.

The difference between the experiments in Cases 3-(1) and 3-(2) involves the initial setup condition in which culture ants are in black source, Eastern or Western? That means our concern which culture.

We determined that the herding of Eastern society in Case 3-(1) sticks more than Case 1. The herding of Western society in Case 3-(2) fluctuates more than Case 2. The experimental results show that they are impacted by group distance and are influenced increasingly more by the original cultural consciousness. The individualist is more toward individualism. The collectivist is more toward collectivism.

In Case 4, we considered the experimental case of cultural integration or fusion. A society has two different cultures that accept each other and the respective cultures one hundred percent. The difference between experiments in Case 4-(1) and 4-(2) involves the initial setup condition in which culture ants are in black source, Eastern or Western. Regardless of which initial condition the experiments start, they have the consistent result and the same simulating process of herding behavior. The experimental results produce a new culture similar to a higher culture's group to integrate two different cultures. We can realize the interaction of two cultures in a society and accommodate each other. They will create a new culture; the extent of their new culture and characteristics of the collective consciousness will be moderated between two cultures.

Cases 5-(1) and 5-(2) predicted herding behavior of which country culture. The results observe individualism value (IDV) of Case 5-(1) is 0.80 closing to Canada culture behavior and Case 5-(2) is 0.30 closing to Hong Kong culture behavior.

## 4 Conclusion

The paper presents the effect of financial market herding behavior on national culture of individualism versus collectivism. We take a step in the direction of inserting cultural factors between simulating agents and herding behavior in financial markets. Furthermore, we create a model to simulate and forecast herding behavior with different cultural styles. Such findings underscore the importance of recognizing cultural styles with herding behavior. Finally, three of these findings are worth summarizing:

- (1) We establish a culture-sensitive agent based model and observe the swing process with herding behavior in financial markets.
- (2) We can reproduce and recognize the important herding behavior of the stock market through a mechanism of simulation with cultural factors.
- (3) We consider the differences between individual and collective consciousness through national culture. Additionally, we examine how the investors within the stock market face the same issue and determine how to evaluate integration or divergence of different cultures.

Future research is obviously required, but this is an exciting first step. We will hopefully clarify the impact from other dimensions, such as power distance, uncertainty avoidance, long-term orientation, masculinity of Hofstede's national culture, determining the herding behavior pattern (transiting frequency and type), and research more complex culture-sensitive herding behavior regarding social networks in the financial market.

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