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Consumers' Behaviours Towards Green Food: The Role of ICTs

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Abstract. Consumers have become increasingly interested in green food as their environmental knowledge has improved since the COVID-19 pandemic. Examining variables that affect green food usage is thus crucial. However, there is a literature gap in this matter, i.e., studies that examine the role of ICTs on consumer's green knowledge and behavior toward green food remain scarce as prior studies focused on the role of internal factors such as risk perception, motivations, food neophobia, and consumers' trust. This study seeks to investigate in what way consumers' green knowledge influence their purchases of green food and how ICT usages moderate this link. This research aims to test the theoretical framework through the construction of a Hidden Markov Framework (HMF). In various usages of information and communication technologies (ICTs), the utilization likelihood of green food with varying green knowledge are calculated using the HMF. Additionally, the shift likelihood of green food buying is computed using a dynamical period cycle. Furthermore, the notions of continuity, reliance, and willingness in green food utilization are explained and calculated in this research. In order to confirm the accurateness of the likelihood computation and the consistency of the HMF, the method is utilized to predict the consumer behaviors of the actual situation. The findings verify that the usage of ICTs has a moderating influence on the positive correlation between consumer's green knowledge and their behavior toward green food. Future studies can use our framework in different contexts such as another emerging country or another green product, and test the framework using different analytical tools such as Artificial Neural Networks and different approaches such as Multi-criteria Decision Making.

Keywords. Green knowledge, consumer behavior, green food, sustainability, ICT

1. Introduction

Individuals are experiencing increasing and more severe pollution from product consumption due to rising material consumption [1-3]. People are therefore forced to reassess their consuming habits. Green consumption has grown in popularity as a means of helping people slow down environmental destruction [4,5]. Green consumption practices are a key to the green economy and a major factor behind sustainable development. Public is largely concerned about its advantages, which include high resource utilization efficiency and ecology friendliness [6]. Given the significant impact of green consumer behavior on the environment, government must find practical ways to encourage green consumer behavior to develop an ecological civilization.

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Considerable focus has been given to the utilization of ICTs within ecological conservation [7]. Prior research has primarily concentrated on enhancing manufacturing and energy efficiency, minimizing environmental contamination [8], and boosting firm performance [9]. Through developing intelligent transport infrastructure and smart city, ICTs possess the potential to decrease worldwide CO2 emission [10]. However, it may not be feasible for many nations with low-income [11]. The usage of ICTs might boost electricity and energy usage; hence, it also negatively affects the environment [12].

ICTs' usages have a significant influence on various aspects of human life, including shopping habits, mobile payments, medical practices, and scientific research [7]. ICTs has major potential to influence and modify consumers' behaviors. Specifically, the advent of cloud computing and internet of things has significantly altered the public's consuming patterns. Consumers can utilize search engines to find information, read comments, purchase green food on websites, and assess reviews on social networks prior to buying green food. ICTs can also create a resource-efficient communication system facility and develop an emission-reducing and resource-conserving business chains. ICTs aim to attain cost-effective usage of energies in the real sector [13].

The swift advancement of digital technologies [14, 15] and social media platforms can effectively disseminate policies and knowledge pertaining to green food, thereby subtly influencing consumers' purchasing habits for green food [16]. This is evident in the current authoritative survey data. Tweets concerning global warming on social networks have a favorable impact on people's behaviors [17]. Moreover, the Internet guides consumers towards enhancing their awareness of environmental risks, hence encouraging their consumption of green food [18]. In summary, the utilization of ICTs can enhance the manufacturing and utilization of green food by impacting the availability of such food, fostering the growth of the entire value chain of green food, and conducting widespread promotion of policies to influence an individual's perception of consuming green food. However, there is a literature gap in this matter, i.e., studies that examine the role of ICTs on consumer's green knowledge and behavior toward green food remain scarce as prior studies focused on the role of internal factors such as risk perception [19], motivations [20], food neophobia [21], and consumers' trust [22].

Thus, this paper utilizes questionnaires from Chinese consumers to investigate the correlation of ICT usage and green food consuming patterns. Specifically, this work aims to tackle these research queries (RQs) using mathematics and empirical data:

a) RQ1: What is the impact of consumers' green food knowledge on their behavior toward green food usage?
b) RQ2: What is the moderating role of the ICT usage in the positive effect of consumer's green food knowledge on their behavior toward green food usage?

2. Conceptual Framework

Fig. 1 displays the conceptual framework, which has three variables: (a) green knowledge as predictor, (b) consumer behavior toward green food as predicted variable, and (c) ICT usages as moderator. It has two hypotheses: (a) H1: Green knowledge positively affects consumer behavior toward green food, (b) H2: ICT usages moderate the link between consumer's green knowledge and their behavior toward green food.

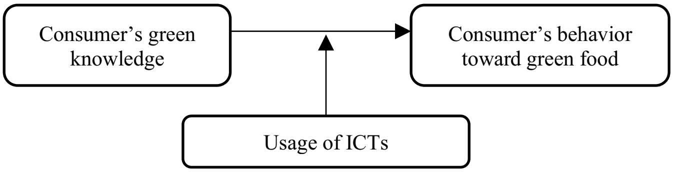

Figure 1. *Conceptual framework*

3. Methodology

3.1. Sample and procedure

The sample size of this study is 371 Chinese consumers in Beijing, the capital of China. The pilot test was conducted on 15 participants to improve the wording and contexts. The questionnaire was made in English and then translated into Chinese using a professional translator. The survey forms were spread arbitrarily between September and November 2023. The returned data were obtained from 355 participants, of which 311 are complete and valid for the data examination.

3.2. Measures

Initially, the authors employ the mean and standard deviation algorithm to categorize the green knowledge, ICT usage, and consumer behavior of green food based on their level, ranging from low to high. The authors acquired a total of 6 measures of green knowledge, 3 indicators of the ICT usage, and 5 of consuming behaviors (see Table 1). The measurement items of the ICT usage are as follows: a) Frequency of reading scientific publications about green food on social media platforms like QQ and WeChat to understand the concept of green consumption, (b) Frequency of browsing postings about green food on social networks, (c) Frequency of monitoring air and water pollutions using wearable wireless sensor and GIS technology. The scales range from great frequency (at least once a month), medium frequency (once in 2-5 months), and small frequency (maximum once in 6 months).

Table 1. Variables' scales and descriptions

Variable	Scale	Description
Consumer's green knowledge (CGK)	CGK0	Do not know about the effects of food on the environmental condition
	CGK1	If the designs of the food products can lead to contamination
	CGK2	If the food packing has low-CO2 and ecological safeguard
	CGK3	Understand whether the main food's components will cause pollutions
	CGK4	Whether manufacturing and distribution can lead to ecological pollutions
	CGK5	If the usage and retrieval of food can contaminate the ecosystem
Usage of ICTs (ICT)	ICT0	Small frequency (maximum once in 6 months)
	ICT1	Medium frequency (once in 1-5 months)
	ICT2	Great frequency (at least once a month)
Consumer behavior toward green food (CBH)	CBH0	Identify if food causes environmental damage when being consumed
	CBH1	During consumption, it is recognized if food is environmentally friendly, meets consumers' needs and with reasonable price
	CBH2	Food unsafe to the environment are refused to be consumed
	CBH3	Take environmentally friendly consumption as possible
	CBH4	Be willing to pay higher price to the green food

3.3. Method of data analysis

To address research queries and assess the hypotheses, this research utilizes the trained grid-driven Bayesian network to accurately calculate the restricted likelihood. Moreover, it is necessary to expand the fixed framework into a vibrant Bayesian network that incorporates period sequence data. Through data collection, a Hidden Markov Framework (HMM) is created using the observed sequence of green knowledge and usage of ICTs. It is subsequently used to deduce the unknown sequence of consumer behavior toward green food. HMM consists of a sequence of hidden determinants, where each determinant is linked to a likelihood density function that describes the likelihood of observing a particular value [23]. Here, the framework represents M as determinant (D) that describe consumer behavior of green food. Hence:

$$CBH = \{D_1; D_2; /; D_M\}$$

The Markov sequence is qt for period t, subsequently: $q_t \in CBH$. N is examination determinant totality, gauging green knowledge and ICT usage. Thus:

$$GRP = \{V_1; V_2; /; V_N\}$$

The examination score for period t is Ot, subsequently: $O_t \in GRP$. The shift likelihood of the framework in distinct is A, subsequently:

$$A = [a_{ij}]_{M\times M}$$

In which: $a_{ij} = P(q_{t+1} = D_j | q_t = D_i); M \geq j; i \geq 1$

This represents the likelihood for the determinant Dj occurring in later period t+1, assuming that at every given moment the determinant is Di. The consumer behavior determinant i of green food, the likelihood of seeing a specific mixture (j) of green knowledge and usage of ICTs is:

$$B = [b_{ij}]_{M\times N}$$

In which: $b_{ij} = P\ (O_t = V_j | q_t = D_i); M \geq I \geq 1; N \geq j \geq 1$. This signifies the likelihood to examine Oj, assuming Di as determinant, at every period, and p is the early determinant likelihood: p = (p1; p2; …; pM), where: $p_i = P(q_1 = D_i); M \geq i \geq 1$

Fig. 2 signifies the concealed determinant of consumer behavior of green food at period t, denoted as q_t. O_t is the union of green knowledge and ICT usage at a given moment, t; The determinant shift matrix is A, the examination likelihood matrix is B.

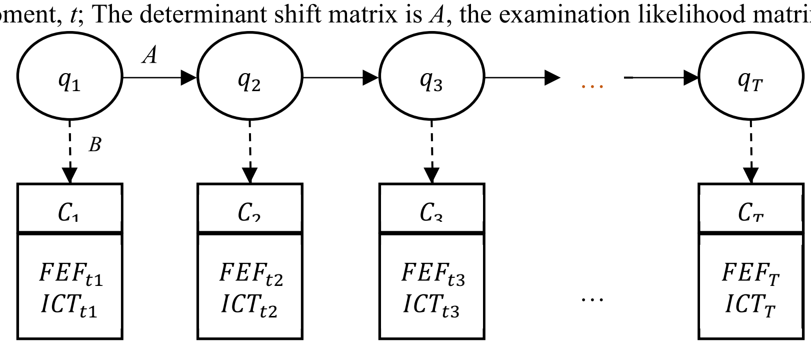

Figure 2. *Diagram of HMM process*

The HMM is formally defined as a tuple l = (A, B, p). The authors own three conventional algorithms; the Baum-Welch algorithm (BWA), the Viterbi, and the backward-forward algorithms (BFA).

The BFA is employed to address these issues: given an outlook series column C = (C1, C2,…, CT) (where t represents the duration of the examination sequence) and the framework l=(a, B, p). The method consists of the forward the backward processes [24].

The forward variable at period t (1 < t ≤ T) for a given framework l is the likelihood of observing C until period t and being in determinant qi in period t. Thus, the expression, at(i)= P(C1, C2, …, CT, Dt=qi|l), in which i=1, 2, …, m (the number of concealed determinants), and t ranges from 1 to T. Dt denotes the determinant at period t. The first answer at(i) (with i=1, 2, …, M) is a1(i)=pibi(C1). With t=2, 3, …, T, this value is:

$$\alpha_t(i) = \left[\sum_{j=1}^{N} \alpha_{t-1}(j)a_{ji}\right]b_i(C_t) \quad (1)$$

The term " at-1(j)aji " represents the likelihood of the mutual occurrence where C1, C2, …,Ct-1 are observed (denoted by at-1(j)), and a shift from determinant qj exists at period t-1 to determinant qi at period t (denoted by aji). The term " bi(Ct)" represents the likelihood of observing Ct from determinant qi. Likewise, the backward factor bt(i) can be defined as the likelihood of the examination order from period t+1 to finished, with determinant qi at period t and the framework l. Subsequently, bt(i)=P(Ct+1, Ct+2, …, Ct|St=qi, l). The value of bT(i)=1 is the starting score bt(i) (i=1, 2, …, M). It is outlined (for t=T—1, T—2, …, 1) below [21]:

$$\beta_t(i) = \sum_{j=1}^{N} a_{ij}b_j\,(C_{t+1})\beta_{t+1}(j) \quad (2)$$

The examination Ct+1 is developed from determinant qj. Subsequently the BWA instructs the HMM using static examinations C=(C1, C2, …, CT), with the framework l=(A, B, p). BWA maximizes the likelihood P(C|l) by making adjustments to A, B, and p. These parameters are updated in an iterative manner, with t = 1, 2, …, T—1 (i, j=1, 2, …, M). The update process is:

$$\xi_t(\mathrm{i,j}) = \frac{\alpha_t(i)a_{ij}b_j(O_{t+1})\beta_{t+1}(j)}{P(C|\lambda)} \quad (3)$$

$$\gamma_t(i) = \sum_{j=1}^{N} \xi_t(\mathrm{i,j}) \quad (4)$$

The variable xt(i, j) represents the likelihood of an effect achieving determinant qi at period t and shifting to determinant qj at period t+1. By aggregating a pool of examinations, it may gauge the predicted quantity of shifts to or from a determinant [25]:

$$a'_{ij} = \frac{\sum_{t=1}^{T-1}\xi_t(\mathrm{i,j})}{\sum_{t=1}^{T-1}\gamma_t(\mathrm{i})} \quad (5)$$

$$b'_j(k) = \frac{\sum_{t=1,O_t=k}^{T}\gamma_t(\mathrm{j})}{\sum_{t=1}^{T}\gamma_t(\mathrm{j})} \quad (6)$$

$$\pi'_i = \gamma_1(\mathrm{i}) \quad (7)$$

Iteratively, the authors re-estimate the parameters l' = (A', B', p'), in which p'={p'i}, B'={b'j(k)} and A'={a'ij}, being expressed mathematically (5)e(7).

The Viterbi method is employed as a predictive algorithm. To enter a set of 1 … T period examinations, denoted as C, into HMM l, follow these steps:

$$C = \{C_1; C_2; /; C_T\}; C_i 2GRP$$

The likelihood matrix, denoted as d, represents the consumer behavior of green food. Additionally, it provides us with the vector J, which represents behavior with the highest likelihood. The Viterbi algorithm is (the initiation occurs at period t=1):

$$\delta_1(i) = \pi_i b_i(C_1) \quad (8)$$

$$\psi_1(i) = 0 \quad (9)$$

For every period point t=2, …, T, it computes the optimal fractional effect likelihood for the sorted performance j(M≥j≥1) using iterative approach.

$$\delta_t(j) = {}^{max}{}_i\delta_{t-1}(i)a_{ij}b_j(C_t) \quad (10)$$

At every period t(1 < =t < =T), the authors utilize the argmax utility to determine the encrypting that corresponds to the behavior with the highest likelihood.

$$\psi_t(j) = {}^{argmax}{}_i\delta_{t-1}(i)a_{ij} \quad (11)$$

This study employs procedures below to predict consumer's green food usage: (a) The obtained questionnaires are used to assess green knowledge, ICT usage, and green food usage; M and N parameters are obtained, (b) Records from questionnaires provide the initial vector p for each consumer based on M and N, (c) The records serve as the training set for data analysis, and the BWA is used to reevaluate matrices A and B, and (d) The Viterbi method is employed to determine the optimal output likelihood for each determinant and the determinant order of every behaviour that has the highest likelihood.

4. Analysis and outcomes

Table 2 displays the likelihood calculation outcomes. Firstly, every value in Table 2 signifies a likelihood of consumers' behaviors toward green food initiated by their green knowledge, which is all significant and positive. It implies that consumers' green knowledge positively and extensively affects their behavior toward green food. Thus, it answers the first RQ. Secondly, Table 2 also reveals a noteworthy moderating effect of ICTs. The greater the green knowledge, the more likely it is that the extensive usage of ICTs will cause big increase in consumer behaviour towards green food. Hence, it answers the second RQ. Table 3 exhibits consumer behavior transitioning from qt to qt+1.

Table 2. Likelihood of green food consumption due to usage of ICTs

	CBH0	CBH1	CBH2	CBH3	CBH4
CGK0(ICT0)	82.264	0.070	0.017	0.015	0.019
CGK1(ICT0)	0.081	0.079	0.031	0.027	0.025
CGK2(ICT0)	0.081	0.088	0.045	0.042	0.031
CGK3(ICT0)	0.077	0.090	0.059	0.057	0.038
CGK4(ICT0)	0.072	0.092	0.073	0.071	0.043
CGK5(ICT0)	0.063	0.088	0.086	0.086	0.049
CGK0(ICT1)	0.070	0.055	0.022	0.019	0.030
CGK1(ICT1)	0.066	0.057	0.036	0.035	0.040
CGK2(ICT1)	0.061	0.059	0.050	0.049	0.049
CGK3(ICT1)	0.057	0.061	0.063	0.064	0.058
CGK4(ICT1)	0.048	0.059	0.077	0.078	0.070
CGK5(ICT1)	0.039	0.052	0.090	0.093	0.079
CGK0(ICT2)	0.059	0.040	0.026	0.025	0.042
CGK1(ICT2)	0.050	0.035	0.040	0.041	0.057
CGK2(ICT2)	0.041	0.023	0.054	0.056	0.073
CGK3(ICT2)	0.032	0.025	0.068	0.071	0.088
CGK4(ICT2)	0.023	0.020	0.082	0.086	0.105
CGK5(ICT2)	0.014	0.015	0.095	0.101	0.120

Table 3. The determinant transition likelihood matrix of green food consumption

q_t	q_{t+1}				
	CBH0	CBH1	CBH2	CBH3	CBH
CBH0	0.574	0.166	0.071	0.024	0.181
CBH1	0.087	0.395	0.169	0.156	0.209
CBH2	0.105	0.153	0.404	0.212	0.141
CBH3	0.101	0.161	0.210	0.394	0.148
CBH4	0.101	0.156	0.129	0.115	0.516

5. Discussion

This research provides empirical evidence that the usage of ICTs has a moderating influence on the positive correlation between the green knowledge and the consumer behavior of green food. These findings support earlier studies regarding digital technology usage and consumer behaviors [26, 27]. Furthermore, it does a quantitative analysis to examine the moderating impact of ICTs usages. The findings support green food makers in making informed strategic decisions during the research and development and design phases. They also assist ICT firms in making accurate assessments of market potential, customer reliance, and risk prediction. The outcomes also serve as a point of reference for government in implementing policies related to ecological conservation.

The findings from Tables 2 and 3 serve as a point of reference for green enterprises to conduct market analyses and develop strategic plans. Also, it offers direction for ICT usage in firms to produce eco-friendly products and services. The research also evaluates the accuracy of the HMM outcomes. By employing HMM to determine the path with the highest likelihood for segmenting the sample, the authors may obtain a precise identification rate. HMM algorithm has a higher rate of accuracy in identification. As the sample size increases, the accuracy also increases. The estimating data and method can serve as a valuable reference in formulating environmental regulations by government as the main supporter for sustainable technology adoption and growth [28,29].

6. Conclusion

ICTs has become integral to the R&D, manufacture, and sales of green food. Thus, this research develops a theoretical framework that investigates the causal link between green knowledge and the use of green food. The article examines how the attitude towards consuming green food influences the link between the green knowledge of these products and actual consumer behavior. It also explores how the use of ICTs can affect this link. This work empirically tests the conceptual framework and hypothesis. The findings indicate that: (1) Green knowledge positively affects green food usage; (2) ICT usage moderates the positive effect of green knowledge on green food usage. As ICT usage increases, the positive link between green knowledge and consumer behaviour toward green food strengthens. It supports the previous outcomes [30], which confirmed the significant moderation of ICT usage in strengthening consumers' behaviours toward green energy usage. The findings support the progress of green food consumption and serve as a point of reference for relevant theoretical and practical implementations.

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