WeChat adoption among older adults and urban-rural differences in China

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ABSTRACT: At the intersection of social digitization and population aging, the challenge of older adults fitting into digital life is becoming more prominent. To understand how to help older adults adopt digital life, this study builds upon the Technology Acceptance Model (TAM) and developed the Digital Technology Motivation Interaction Model (DTMIM) to study the complex effects of autonomous motivation (perceived usefulness, perceived ease of use, perceived enjoyment), controlled motivation, and digital feedback on WeChat adoption among older adults, as well as the urban-rural differences. The results of the questionnaire survey and Fuzzy-set Qualitative Comparative Analysis (fsQCA) show that: First, no single construct is a necessary condition for a high (non-high) attitude toward using (ATU) or high (non-high) actual using (AU). Second, we identified two configurations that trigger high ATU including the autonomy-motivation type and digital feedback under motivational synergy, and three configurations that enable high AU including motivational synergy type, digital feedback under autonomous extrinsic motivation, and digital feedback under motivational synergy. Third, the configurations of high ATU and high AU show significant differences between urban and rural areas. Autonomy motivation plays a universal role in urban older adults' WeChat adoption, while digital feedback is critical for rural older adults. The configuration analysis of DTMIM and urban-rural differences is not only an adaptive improvement of TAM, but also provides new methods and perspectives for future research on the adoption of digital technology.

Keywords: Older adults; Wechat; DTMIM; fsQCA; Urban-rural differences

1. Introduction

At the intersection of social digitization and population aging (Wu & Song, 2021), the challenge of older adults (aged 60 and older) adapting to digital life is becoming increasingly prominent (Huang, 2023). On the one hand, the global older population is growing rapidly, with predictions that the proportion of older adults will increase from 9 per cent to 18 per cent from 2020 to 2100 (Department of Economic and Social Affairs, 2019). On the other hand, the intensive integration of the digital economy and the real economy continuously improves the level of networking, digitization, and artificial intelligence in modern society. A large number of digital businesses or models, such as instant messaging, online shopping, online healthcare, and online payments, have profoundly changed daily lifestyles (Lisha et al., 2017). In short, social digitization and population aging are irreversible trends. However, older adults encounter psychological

and physiological barriers that hinder their adoption of digital technology (Tandon et al., 2023), making it challenging for them to keep up with the rapid changes in digital life (Seifert, Cotten, et al., 2021; Song et al., 2021). This results in the loss of older adults' fair rights to benefit from the developmental opportunities and social conveniences of digital technology. It in turn affects their psychological and physical health (Liu, Wu, et al., 2021) which is becoming a new social inequality (Department of Economic and Social Affairs, 2021; Seifert, Cotten, et al., 2021).

Furthermore, the significant urban-rural dual structure in Chinese society has led to digital inequality and differences in adoption mechanisms among older adults in urban and rural areas (China Internet Network Information Center, 2023). On the one hand, the uneven level of economic and social development, as well as differences in the priority of national information technology development strategies, have led to inconsistent levels and speeds of digitalization in urban and rural areas of China (Lu et al., 2023). The basic infrastructure in rural areas is underdeveloped, and the utilization and popularization rate of digital life are relatively low. There are significant disparities in access to digital life such as digital entertainment, healthcare, and transportation between urban and rural areas, leading to unequal opportunities and costs for older adults to adopt digital life (Liu & Wang, 2021). On the other hand, the different income levels, education, and health conditions among older adults in urban and rural areas result in significant differences in digital abilities and endowments (Jiang et al., 2021), ultimately leading to different ways of digital adoption. Therefore, to help older adults in adopting digital technology, we address the question 'How can older adults embrace digital technology?' Furthermore, digital inequality is especially pronounced between urban and rural areas. We will further analyze 'What are the differences in driving mechanisms between urban and rural areas?'

Despite numerous research achievements, there are still some existing gaps regarding the aforementioned questions. Existing studies employ the TAM to analyze users' attitudes and behaviors in accepting and adopting new technologies, new ideas, and new things, and is extensively utilized in research on digital technology adoption among older adults (C. Wang et al., 2023; Lu et al., 2009). These studies generally found that perceived usefulness (PU), perceived ease of use (PEU), and perceived enjoyment (PE) are important factors in promoting the adoption of smartphones (Huang, 2023), online shopping (Wu & Song, 2021), and virtual reality exergames (Xu et al., 2023) among

older adults (Braun & Michael, 2013; Seifert & Charness., 2022; Xu et al., 2023). Despite its universal explanatory power, TAM assumes that the user's adoption of digital technology is an autonomous will without any other constraints (Davis, 1986), ignoring social situational factors, thus offering only a universal response to these research questions. Especially the lack of adaptive improvements for the following two scenarios. On the one hand, population aging and social digitalization have caused older adults to suffer from 'digital exclusion' (Liu, Wu, et al., 2021; Seifert, Cotten, et al., 2021; Song et al., 2021). In the digital era, digital devices and applications such as WeChat have become integrated into daily life, encompassing activities such as travel, medical treatment, consumption, public business, and entertainment (Lisha et al., 2017). However, this unstoppable trend has resulted in various inconveniences for older adults who may struggle with comprehension and acceptance (Seifert, Cotten, et al., 2021). Coupled with its increasingly rich and powerful functions, older adults are forced to use WeChat due to the control of daily digital life (Liu, Wu, et al., 2021). Unfortunately, a limited number of studies endeavored to extend TAM with autonomous motivational factors such as self-efficacy (Xu et al.,2023; Huang, 2023), perceived risk (X. Wang, 2023), and technological anxiety (Tandon et al., 2023; C. H. Wang & Wu, 2022) to enhance the model's explanation of the older adults' acceptance of digital technology. In addition, these studies often neglect the crux of older adults suffering from 'digital exclusion'. On the other hand, China's unique back-feeding culture (the consciousness, spirit, and values of offspring repaying kindness to their seniors) has given birth to the emergence of significant factors that differ from TAM. Although some studies have paid attention to the phenomenon of back-feeding culture in Chinese families (Song et al., 2021), few studies have integrated back-feeding culture with the original TAM (Lu et al., 2009; Liu, Wu, et al., 2021), which hinders the comprehension of this endogenous and sustainable auxiliary force.

Furthermore, older adults are a demographic characterized by multifaceted interactive psychology and motivation. Therefore, WeChat adoption among older adults with varying characteristics in different situations is not a homogeneous condition (Taipale et al., 2021). Previous research has analyzed the promoting and hindering factors from the perspectives of the subject, object, and support environment based on theories such as the Diffusion of Innovations Theory, Unified Theory of Acceptance and Use of Technology, Uses and Gratifications Theory, and Expectation-confirmation Theory.

The most extensive analysis is conducted from the subject perspective: The physical function, subjective norms, digital literacy, socioeconomic status, cognitive level, and other physical or psychological factors of older adults are weak, resulting in insufficient motivation and ability to adopt digital devices (Liu, Wu, et al., 2021). The focus of object perspective research is on the universal design of digital products and content, which has long neglected the special needs of older adults (Chou et al., 2013; Charness & Boot, 2022). From the perspective of the supportive environment, scholars emphasize the significance of providing scientific and systematic guidance and training for older adults to adopt digital life (Seifert, Cotten, et al., 2021), as well as support from family members (Wright, 2000; Liu, Wu, et al., 2021). However, the majority of existing research utilizes methods such as linear regression and structural equation model to examine the net effect between variables, neglecting the complex causal relationships among multiple conditions of inter-dependence, combination effect, and multiple conjunctural causation on older adults' attitudes and behaviors towards WeChat (Lisha et al., 2017; Huang, 2023).

Moreover, scholars and policymakers have recognized the serious digital inequality between urban and rural older adults in China and its serious consequences (China Internet Network Information Center, 2023; Liu, Wu, et al., 2021). In recent years, scholars have begun to explore the underlying reasons and have found that the main gaps are the digital abilities and literacy of older adults (Jiang et al., 2021), as well as external digital infrastructure (Lu et al., 2023). However, previous studies did not provide scientific and systematic solutions, and they lacked sufficient consideration for the integration of digital technology among rural older adults. Particularly, they neglected the significance of analyzing urban-rural differences (Song et al., 2021). The lag and gap in prior studies have hindered progress in mitigating the digital inequality between urban and rural older adults.

To rectify the limited adaptability of TAM to encompass ‘digital exclusion’ and back-feeding culture, we extended TAM by adding the factors of controlled motivation (CM) and digital feedback (DF) and developed the DTMIM. We then avoided the limitations of traditional methods in analyzing the ‘net effect’ of individual antecedents to outcomes (Lisha et al., 2017; Huang, 2023), and used fsQCA to study the complex ‘configuration effect’ of WeChat adoption among older adults from an overall perspective (Furnari et al., 2021). Furthermore, we analyzed the urban-rural differences

of the 'configuration effect' to provide a theoretical basis for mitigating digital inequality.

2. Literature review and model construction

2.1. Literature review

Among intelligent products, WeChat is a representative technology of digital life. In addition to social interaction, it has been applied to various aspects of life, such as clothing, food, housing, and transportation (Lisha et al., 2017). WeChat's extensive functionality and user-friendly features offer an accessible, cost-effective, and replicable pathway for older adults to integrate into the digital world (Zhang et al., 2023), This also serves as an example and opportunity to illustrate how older adults can integrate into digital life. Therefore, to analyze the primary factors and driving mechanisms behind WeChat adoption among older adults. This study attempts to adaptively improve TAM by integrating Self-Determination Theory (SDT) and Digital Feedback Theory (DFT), resulting in the DTMIM.

2.1.1. Technology Acceptance Model

Davis (1986) first proposed TAM, which is based on the Theory of Planned Behavior. It includes six variables: external variables, perceived ease of use (PEU), perceived usefulness (PU), attitude toward using (ATU), behavioral intention to use, and actual usage (AU). TAM is an important theory for studying users' attitudes and behaviors towards information systems. It was first used to explain the high investment and low utilization rate of information technology. Due to its simple structure and strong explanation for users' attitudes and behaviors in accepting new technologies, new concepts, and new things, TAM has been widely applied in various research fields such as social media (Braun, 2013), online healthcare (C. Wang et al., 2023), and instant messaging (Lu et al., 2009).

PU and PEU are two essential basic variables for TAM. However, TAM lacks a sufficient explanation for user acceptance behavior in complex environments, especially when users have resistance to technology (Wu & Song, 2021). Therefore, adjustments should be made continuously based on the research context and research object. Multiple important adjustments have occurred: (1) In 1996, Davis & Venkatesh found that ATU could only partially explain the impact of PU on AU, and removed the ATU from TAM. Thus, our study chose ATU and AU as outcome variables, which can further reveal why ATU cannot be fully transformed into AU. (2) Venkatesh & Davis (2000) emphasized the importance of external variables and introduced variables of social influence and cognitive tools to construct TAM2. (3) Venkatesh integrated 8 models and theories to construct the Unified Theory of Acceptance and Use of Technology (UTAUT) in order to summarize the influencing factors of information technology acceptance. (4) In 2008, Venkatesh and Bala proposed TAM3, suggesting that PU and PEU have interactive effects, which also indicates the importance of studying complex causal relationships through QCA.

It is worth noting that Davis (1992) believed that in addition to external motivations such as PU and PEU, internal motivations also play a key role in the motivation for technology acceptance. Extrinsic motivation is the behavioral motivation triggered by an external stimulus, while intrinsic motivation is the behavioral motivation triggered by an individual's desire to perform a certain activity (Davis, 1992). Therefore, Davis introduced perceived enjoyment into TAM as an intrinsic motivation. He believes that when PU is regarded as the main factor affecting behavioral intention, PE can be used to explain large shifts in behavioral intention to technology. Entertainment is an important incentive for older adults in China to use digital technology (China Internet Network Information Center, 2023), so introducing PE into TAM significantly strengthens its explanation of this issue.

2.1.2. Self-Determination Theory

SDT is a meta-theory of human motivation and personality development proposed by Deci & Ryan in the 1980s. SDT assumes that people are active individuals with the support of society and the external environment, who tend to self-integrate, improve, and learn. The relationship between the individual and the environment is an organic interaction (Ryan & Deci, 2019). SDT divides people's motivation for engaging in

activities into three types: Intrinsic Motivation, Extrinsic Motivation, and Amotivation. Afterwards, Ryan & Deci (2000) reclassified motivation into two types: autonomous motivation and CM, to distinguish whether individual behavior is autonomous behavior of free will or controlled behavior dominated by the environment. Autonomous motivation refers to having sufficient will and preference when engaging in activities, including autonomous internal and external motivation (Ryan & Deci, 2000). Among them, autonomous internal motivation is a typical manifestation of the positive integration tendency of human nature assumed by SDT, originating from the enjoyment or interest in the activity itself, representing a highly autonomous and self-determination state (Tandon et al., 2023). Therefore, PE belongs to autonomous internal motivation. Autonomous external motivation indicates an individual's recognition and pursuit of the value and significance of activities, and can internalize external rules as part of their own needs. Therefore, PU and PEU belong to autonomous external motivation (Ryan & Deci, 2000; Davis, 1992). CM refers to the motivation of being compelled or controlled by external conditions or internal psychology when engaging in activities. When basic psychological needs are not in line with the social environment or are not met, external punishments or rewards will force people to generate motivation, and the degree of self-determination in behavior is low (Ryan & Deci, 2019).

Autonomous and controlled motivations interact in promoting individual behavior through antagonistic or synergistic effects. Antagonistic effect refers to the mutual weakening of autonomous motivation and controlled motivation (Ryan & Deci, 2019). The synergistic effect refers to the unique contribution and value of both autonomous motivation and controlled motivation to behavior, and the mutual promotion of the two motivations produces a stronger overall impact. The interactive effects of autonomous and controlled motivations on the adoption of WeChat by older adults vary due to individual and environmental differences. For example, older adults find WeChat interesting, but forcing them to use functions such as WeChat payment and online healthcare may cause resentment and anxiety, reducing their autonomous motivation, which is manifested as an antagonistic effect. However, when older adults lack initial interest in WeChat, peer appreciation not only prove their ability to use WeChat, but also increase their self-efficacy, resulting in stronger enthusiasm for using WeChat, which is manifested as a synergistic effect.

2.1.3. Digital Feedback Theory

DFT originates from Cultural Feedback. Margaret (1970) divided cultural transmission into three basic types: pre-figurative culture, co-figurative culture, and post-figurative culture. Post-figurative culture, also known as 'reverse socialization', refers to the reverse cultural inheritance. When there are cultural differences, barriers, and conflicts between generations, seniors need to learn from juniors in order to complete a new 're-socialization'. Zhou (2000) further proposed 'cultural feedback' from the perspective of cultural transmission and defined it as a process in which the older generation broadly absorbs culture from the younger generation in a rapidly changing era of cultural, values, and social behavior patterns. In the rapid transformation of digital life, generations have different cultural backgrounds and life experiences, which enable them to have different attitudes and abilities when dealing with social changes caused by digital technology. Juniors often have a more open mindset, more natural adaptability, and more flexible acceptance ability (Hjälm, 2012), enabling them to reverse export digital technology skills, knowledge, culture, and values to seniors. Especially in the context of back-feeding culture, DF has clearly become an important part of family life and intergenerational interaction, playing a role in cultivating digital literacy and promoting digital culture among family members (Wright, 2000; Liu, Wu, et al., 2021).

2.2. Model construction

2.2.1. Single condition influence mechanism

- **Perceived usefulness and WeChat adoption among older adults.** PU refers to the convenience that older adults perceive in using WeChat (Davis，1992). Before adopting WeChat, older adults will judge the potential effects. Whether WeChat can improve life satisfaction, physical and mental health, social adaptation, and social participation through digital technology is a key issue for older adults when judging the usefulness of WeChat (Lu et al.,2009). When older adults believe that digital technology is beneficial to convenience, their PU of WeChat will increase, leading to a more positive attitude and further promoting actual behavior (Huang, 2023).
- **Perceived ease of use and WeChat adoption among older adults.** PEU reflects that older adults perceive WeChat as easy to use (Huang, 2023). The development

of digital technology often targets the juniors as ‘opinion leaders’. Differences between juniors and older adults in digital access, usage, and literacy have led to the gradual digital marginalization of older adults (Song et al., 2021). Moreover, due to the psychological and physical characteristics of older adults, such as cognitive decline and rigid thinking (Shulman & Gitterman, 2005), many older adults are often hindered from using new technologies. Therefore, PEU is an essential factor in analyzing the acceptance of WeChat among older adults (Lu et al.,2009). The level of compatibility between the subject and object, as well as the psychological stereotype of fear of difficulty, determine PEU of WeChat among older adults. The stronger these two factors are, the more negative the attitudes and behaviors of older adults will be when using WeChat.

- **Perceived enjoyment and WeChat adoption among older adults.** As an intrinsic motivation, PE reflects an individual’s sense of pleasure and happiness while using WeChat (Davis, 1992), and can influence their decisions to continue using it (Lu et al.,2009). When older adults perceive the enjoyment, they are more likely to have higher satisfaction and positive feedback on their inner motivation (Lisha et al., 2017). This makes them more willing to accept and use other digital technologies and features within WeChat.
- **Controlled motivation and WeChat adoption among older adults.** CM has various effects on older adults with different characteristics. Digital technology has significantly changed daily life, including travel, healthcare, and shopping. However, due to limitations in acceptance and understanding, some older adults may feel controlled by digital technology (Wu & Song, 2021). While some individuals may actively engage in the digital environment, striving to adapt and learn from WeChat, others' basic psychological needs are restricted by CM (Ryan & Deci, 2019). This can lead to fear of difficulties, tension, stress, and even resistance or defensive behaviors towards WeChat (Lu et al., 2009; Seifert, Cotten, et al., 2021; Tandon et al., 2023). The impact of CM can vary from person to person, either hindering or promoting the acceptance of WeChat among older adults.
- **Digital feedback and WeChat adoption among older adults.** DF refers to the guidance and assistance provided by younger generations to older generations in terms of digital access, usage, and literacy (Correa, 2013; Zhou & Ding, 2020). In

back-feeding culture, younger generations serve as ‘opinion leaders’ and ‘agents’ of technological innovation and diffusion (C. H. Wang & Wu, 2022). Their DF not only aligns with cultural inheritance and technological development but also adapts to the unique modes of interaction and intergenerational relationships in Chinese society (Zhou & Ding, 2020). Since the advent of the internet, older adults have often struggled to use digital technology due to the complexity of information systems and a lack of understanding of usage functions, operating instructions, and device parameters (Hjälm, 2012). Generational differences exist in the capacity to adopt new things. As such, DF serves as an endogenous and sustainable support construct that can help older adults adapt to digital life (Zhou & Ding, 2020). The more in-depth the DF provided by younger generations to older adults, the better they can assist in resolving technical issues. This effectively alleviates technical anxiety and encourages continued use of WeChat among older adults.

2.2.2. Digital Technology Motivation Interaction Model

Various antecedents can influence the adoption of WeChat among older adults. However, the complex interactions among these conditions necessitate a more in-depth analysis of causality. On the one hand, older adults have multiple psychological and behavioral characteristics, so antecedents are interdependent and interactive, often exhibiting complementary or substitutive relationships (Fiss, 2011; Furnari et al., 2021). For example, if older adults find using WeChat enjoyable and believe that features such as video calls, WeChat Moments, and short videos bring them pleasure, they may be more willing to use it. However, if physical limitations such as declining vision, hearing, or comprehension make it difficult to use devices and applications normally, this can hinder their enjoyment and reduce their enthusiasm for using WeChat (Lisha, 2017). As such, there may be a complementary relationship between PEU and PE. Similarly, DF from younger generations regarding usage functions, operating instructions, and device parameters can compensate for low PEU among older adults (Zhou & Ding, 2020). This suggests a potential substitutive relationship between DF and PEU. On the other hand, older adults with different characteristics may have varying needs for the combination of antecedents when adopting WeChat. For example, older adults with higher levels of education may have stronger comprehension and

learning abilities (Song et al., 2021), leading to a lower demand for DF and a higher demand for PE. As such, understanding how various antecedents interact to drive WeChat adoption among older adults is an important question. To address this, we have expanded TAM based on SDT and DF to construct DTMIM, aimed at examining the configuration effects of PU, PEU, PE, CM, and DF on the attitudes and behaviors of older adults using WeChat. DTMIM is shown in Figure 1.

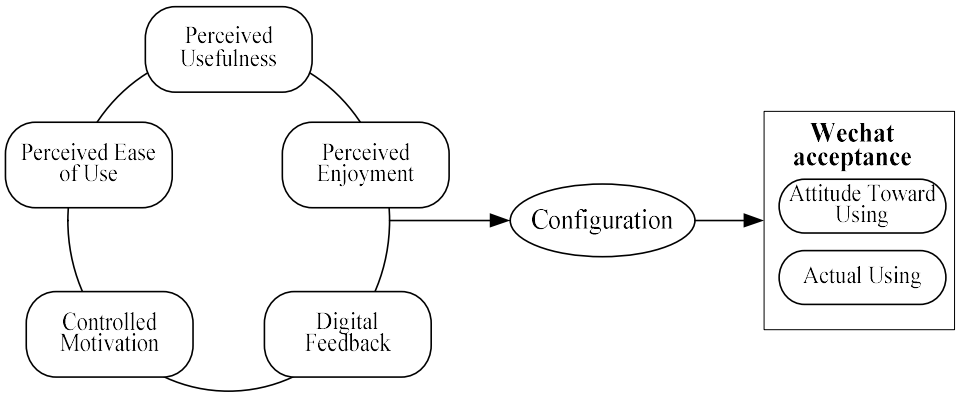

Figure 1. Digital Technology Motivation Interaction Model

3. Method

3.1. Fuzzy-set qualitative comparative analysis

To reveal the intricate causal mechanisms behind WeChat acceptance among older adults, we employed fsQCA to analyze the DTMIM. QCA is a research method developed by American sociologist Charles Ragin in the 1980s. It interprets complex causal relationships of qualitative change effects based on evidence of synergistic relationships between variables. This method emphasizes the combination effect, inter-dependence (complementary and substitutable), and multiple conjunctural causation. It can test whether a single condition or conditional configuration satisfy the necessity and sufficiency of the result (Ragin, 2009). QCA can identify equivalent configurations, helping to clarify the various driving mechanisms that lead to the same result, as well as the complementary and substitutable relationships between antecedent conditions. Therefore, fsQCA utilizes overall configuration to deduce causal logic relationships and can find multiple equivalent paths. This offers a new method and perspective for explaining how older adults integrate into digital life.

3.2. Research instrument

The research questionnaire cited mature scales. Since the items are developed by scholars across various research fields, regions, and populations, the validity of certain items may be compromised. To mitigate this concern, we adjusted the items according to the features of WeChat, real-life scenarios, and cultural differences. Simultaneously, we employed the Delphi method and developed the initial draft of the questionnaire through multiple discussions among scholars specializing in information and media research. All questions were measured on a five-point Likert scale (1=strongly disagree, 2=disagree, 3=not sure, 4=agree, 5=strongly agree). The questionnaire was subjected to a pre-test as part of the preliminary research stage. Overall, 52 pilot data points were collected and subjected to a confirmatory factor analysis (CFA). Three items that exhibited poor reliability and low factor loadings in the analysis were excluded from the questionnaire. The final questionnaire consisted of 35 items encompassing seven latent variables. (Appendix A)

The questionnaire consists of three parts:

Part 1: basic demographic information, for example, age, gender, and education.

Part 2: older adult's acceptance of WeChat, such as whether they have a positive attitude towards using WeChat and whether they frequently use it.

Part 3: Why do older adults use WeChat, including PU, PEU, PE, CM, and DF.

3.3. Data collection

Given the potential challenges that some older adults may face obstacles such as blurred vision or inaccurate cognition, which could compromise the validity of the survey, we have implemented three methods to address these issues. Firstly, four doctoral and six master's students were selected from the research team, and they received rigorous training on the survey's content, subjects, and procedures. Secondly, we distributed questionnaires on-site. Thirdly, a detailed 15-minute introduction about survey content was provided before the survey, followed by in-depth interviews with participants after the survey. These approaches not only facilitated participants in acquiring more detailed information but also rectified any misconceptions regarding the questions and answers. To ensure the representativeness of the sample, our survey was conducted from June to December 2022 using a snowball sampling strategy. The survey team invited their

relatives and neighbors aged 60 and above as the first-round participants when they returned home. Subsequently, participants were encouraged to suggest other suitable respondents for the survey.

We conducted a survey of older adults (60 years and older) in 27 provinces in China and collected a total of 350 anonymous questionnaires, including 176 from urban and 174 from rural. Excluding invalid questionnaires such as individuals without smartphones, without WeChat, or with repeated answers, 206 valid questionnaires remain, with an effective response rate of 58.86%. The valid sample includes 146 urban participants and 60 rural participants. Bentler & Chou (1987) suggested that the sample size should be 5-10 times that of the survey items Therefore, our overall sample size meets the reliability and validity tests. Meanwhile, most QCA studies are of medium or small sample size. Marx and Axel (2010) suggest balancing the sample size and condition size appropriately, and selecting 15 or more samples for analysis of 5 conditions is sufficient. So, the effective sample sizes for urban and rural areas fully comply with QCA. To mitigate the concern of sample selection bias, we validated the validity of the samples using the following two sets of data. On the one hand, since the average life expectancy of Chinese women is higher, the degree of population aging among women is higher than among men. According to the seventh census of the State Council of China, the male-to-female ratio among the population over 60 years old is 48.3:51.7. Therefore, the research sample obtained through our sampling strategy conforms to the normal gender ratio of the current older adults. On the other hand, according to statistics from the China Internet Network Information Center in 2022, the internet penetration rate in urban areas is 83.1 percent, whereas in rural areas, it is 61.9 percent. Therefore, the urban-rural ratio of our valid samples is consistent with the current actual situation of older adults using smartphones and WeChat. The distribution of our research samples is shown in Table 1. The younger older adults, the more likely they are to have used WeChat, with only 22 samples aged 76 and above. Eight participants did not have education, and their low level of knowledge and cognition hindered the use of WeChat. 57.8% of participants do not live with their children, which is a normal phenomenon in China. Children may provide DF to older adults through phone calls or gatherings.

Table 1. Research sample distribution (N=206)

Characteristics	Number	Proportion
Gender		
Male	91	44.2
Female	115	55.8
Age		
60-65	73	35.4
66-70	59	28.6
71-75	52	25.2
76 and above	22	10.7
Education Level		
No degree	8	3.9
Primary school	42	20.4
Junior high school	50	24.3
High school/Vocational school/ Technical secondary school	40	19.4
Junior college/University undergraduate and above	66	32
Residence		
Urban	146	70.9
Rural	60	29.1
Pre Retirement Occupation		
State organs/Enterprises/Institutions	86	41.7
Commercial/Service	20	9.7
Factory/Social services	34	16.5
Agriculture\Forestry\Animal husbandry\fishery	18	8.7
Others	48	23.3
Live with Offspring		
Yes	87	42.2
No	119	57.8

3.4. Reliability and validity

It is necessary to test the reliability and validity of the questionnaire before analyzing DTMIM. The reliability test usually uses Cronbach's α, Composite reliability (CR) and average variance extracted (AVE) are three indicators. Cronbach's α and CR are considered strong indicators of reliability, whereas AVE is a statistical measure used to evaluate the internal consistency and reliability of the constructs (X. Wang, 2023). Mature theories suggest that it is considered acceptable for Cronbach's α, CR, and AVA to exceed 0.7, 0.7, and 0.5, respectively (Hair et al., 2006). This study found that Cronbach's α exceeded 0.7, CR exceeded 0.6, and AVE exceeded 0.5 (see Table 2). These results indicated that the measurement items had a high reliability and good internal consistency.

Validity testing typically involves convergent, content, and discriminant validity of observed variables. In this study, the factor loadings of all items exceed 0.5, indicating that the questionnaire has good convergent validity (Bagozzi et al., 1991). Content validity was ensured in the questionnaire design phase. Initially, the questionnaire items were derived from existing validated scales, providing an initial guarantee of content validity. Furthermore, we used the Delphi method and expert consultation to align the items more closely with the specific background of this study, thereby enhancing the validity of the questionnaire content (X. Wang, 2023). Our study focuses on discriminant validity, which refers to the low correlation and significant differences between latent variables. Fornell & Larker (1981) suggest that a variable has a good discriminant variability if the correlation coefficient between it and the other variables is smaller than the square root of its AVE. The bold values in Table 3 represent the square roots of the AVEs. These values are generally greater than all the other values in their respective columns. Therefore, the measurement model used in this study demonstrated an appropriate discriminant validity.

Table 2. Reliability and convergent validity of constructs

Construct	Question	Factor loadings	Cronbach's α	CR	AVE
PU	PU1	0.840	0.791	0.822	0.616
	PU2	0.753			
	PU3	0.803			
PEU	PEU1	0.832	0.866	0.879	0.654
	PEU2	0.665			
	PEU3	0.838			
	PEU4	0.824			
PE	PE1	0.707	0.863	0.873	0.637
	PE2	0.743			
	PE3	0.844			
	PE4	0.868			
CM	CM1	0.628	0.822	0.83	0.557
	CM2	0.656			
	CM3	0.832			
	CM4	0.818			
DF	DF1	0.821	0.887	0.888	0.570
	DF2	0.856			
	DF3	0.883			
	DF4	0.692			
	DF5	0.608			
	DF6	0.731			
ATU	ATU1	0.848	0.829	0.837	0.565
	ATU2	0.896			
	ATU3	0.841			
	ATU4	0.535			
AU	AU1	0.790	0.821	0.839	0.576

	AU2	0.845
	AU3	0.731
	AU4	0.594

Table 3. Correlation coefficient and square root of AVE

	Mean	SD	1	2	3	4	5	6	7
1 AU	3.762	0.859	0.759						
2 ATU	4.055	0.736	0.737**	0.752					
3 PU	4.320	0.716	0.655**	0.694**	0.785				
4 PEU	3.657	1.035	0.752**	0.682**	0.688**	0.809			
5 PE	3.971	0.878	0.714**	0.733**	0.586**	0.689**	0.798		
6 CM	3.326	0.925	0.676**	0.533**	0.419**	0.597**	0.502**	0.746	
7 DF	4.115	0.672	0.535**	0.664**	0.526**	0.408**	0.567**	0.424**	0.755
8 Place of residence	1.291	0.455	-0.227**	-0.157*	-0.278**	-0.281**	-0.271**	-0.146*	-0.134

Note:*p<0.05, **p<0.01, values on the diagonal are the square root of AVE

3.5. Data calibration

As an ensemble analysis method, the first step in QCA is to convert raw data into ensemble membership scores. We set the 95th percentile, mean, and 5th percentile of the original data as three qualitative anchor points: full-in, crossover, and full-out (Fainshmidt et al., 2019). Table 4 presents the calibration thresholds for the antecedents and outcomes. Additionally, to avoid situations where the fuzzy membership score is 0.5 (which makes it difficult to classify and analyze cases), we added 0.001 to membership scores of 0.5 for fine-tuning (Fiss, 2011).

Table 4. Calibration threshold

Variable Type	Variable	Full-in	Crossover	Full-out
Outcome	AU	5.000	3.630	2.050
	ATU	5.000	4.055	2.750
Condition	PU	5.000	4.320	3.000
	PEU	5.000	3.657	1.750
	PE	5.000	3.971	2.250
	CM	5.000	3.326	1.813
	DF	5.000	4.115	3.000

4. Findings and analysis

4.1. Configuration of Wechat adoption among older adults

4.1.1. Necessity Analysis

Before analyzing the configuration, it is necessary to verify that the conditions are necessary for the results. If the consistency level of an antecedent condition is higher than 0.9, the condition is necessary for a particular outcome (Ragin et al., 2008).

Therefore, we first used fsQCA3.0 software to test whether a single condition is a necessary condition for high ATU (not-high ATU) and high AU (not-high AU). Table 5 shows that the consistency level of all conditions is lower than 0.9, indicating that there is no single condition with a dominant impact on the results for either causal or effect inference. Instead, it is a combination of multiple conditions.

Table 5. Necessity analysis

Condition	High ATU		High AU		Not-high ATU		Not-high AU	
	Consistency	Coverage	Consistency	Coverage	Consistency	Coverage	Consistency	Coverage
PU	0.883	0.815	0.853	0.782	0.526	0.417	0.567	0.453
~PU	0.368	0.475	0.403	0.516	0.767	0.849	0.727	0.812
PEU	0.837	0.836	0.864	0.858	0.532	0.457	0.527	0.456
~PEU	0.456	0.532	0.452	0.523	0.809	0.810	0.836	0.843
PE	0.873	0.839	0.877	0.838	0.586	0.484	0.587	0.488
~PE	0.464	0.566	0.464	0.563	0.806	0.845	0.805	0.851
CM	0.754	0.821	0.802	0.868	0.544	0.510	0.535	0.504
~CM	0.550	0.584	0.542	0.572	0.809	0.738	0.860	0.791
DF	0.830	0.842	0.791	0.797	0.548	0.478	0.602	0.529
~DF	0.485	0.556	0.532	0.606	0.818	0.805	0.769	0.762

4.1.2. Configuration analysis

The variation in sample size and data sources has resulted in different criteria for consistency threshold and case quantity threshold in previous studies on fsQCA. Our sample size is relatively large. To ensure a more comprehensive analysis of appropriate configurations, we set the raw consistency threshold to 0.8, the PRI consistency threshold to 0.7, and the case frequency threshold to 2. The minimization procedure of fsQCA 3.0 computes three solutions based on different simplifying assumptions: complex solution, intermediate solution, and parsimonious solution. Following mainstream research practices (Ragin & Fiss, 2008; Fiss, 2011), we present intermediate solutions supplemented by parsimonious solutions in our results. Conditions that are both intermediate and parsimonious solutions are considered core conditions, while conditions that are only intermediate solutions are considered peripheral conditions, constituting multiple driving mechanisms for ATU and AU. The results are shown in Table 6.

There are two configurations with high ATU and three configurations with non-high ATU. The consistency is higher than 0.8 and the solution consistency is higher than 0.9, indicating that they are sufficient conditions for the specific results. The solution

coverage of the ATU configuration is 0.897, explaining nearly 90 per cent of the reasons for ATU. The solution coverage of the non-high ATU configuration is 0.664, explaining about 66 per cent of the reasons for non-high ATU. There are four configurations with high AU and three configurations with non-high AU. The consistency is higher than 0.8 and the solution consistency is higher than 0.9, indicating that they are sufficient conditions for the specific results. The solution coverage of the AU configuration is 0.752, explaining about 75 per cent of the reasons for AU. The solution coverage of the non-high AU configuration is 0.76, explaining 76 per cent of the reasons for non-high AU.

Table 6. Sufficiency analysis

Condition	High ATU			High AU			Not-high ATU			Not-high AU		
	H1	H2	S1	S2a	S2b	S3	NH1a	NH1b	NH2	NS1	NS2	NS3
PU	●	●	●	•		●	⊗	⊗	⊗		⊗	⊗
PEU	●		●	●	●				⊗	⊗	⊗	⊗
PE	●	●	●	•	•	●	•		⊗	⊗		⊗
CM		●	●	•	•	●		•	⊗	⊗	⊗	
DF		●		●	●	●	⊗	⊗				⊗
Consistency	0.943	0.979	0.964	0.954	0.969	0.965	0.947	0.953	0.953	0.963	0.957	0.957
Raw Coverage	0.735	0.599	0.620	0.647	0.602	0.594	0.405	0.409	0.555	0.668	0.615	0.544
Unique Coverage	0.161	0.025	0.050	0.076	0.032	0.024	0.017	0.026	0.186	0.104	0.051	0.041
Solution Consistency	0.941			0.946				0.936			0.935	
Solution Coverage	0.897			0.752				0.664			0.760	

Note: The black circles (●) and crossed-out circles (⊗) indicate the presence and absence or negation of a condition, respectively. In addition, large circles denote core conditions, small circles denote peripheral conditions, and the blank spaces indicate 'do not care' conditions.

Configurations of high ATU. Configuration H1 is the autonomy-motivation type, including three autonomous motivations of PU, PEU, and PE as core conditions. Older adults have good physical and cognitive abilities that enable them to easily master and use WeChat (Braun & Michael, 2013). They can autonomously transform their perceptions into positive attitudes towards WeChat. For example, older adults with good physical condition and higher education not only have good eyesight and hearing to fully perceive the usefulness and enjoyment of WeChat, but also possess high knowledge and thinking ability to easily accept new things (Song et al., 2021), thus forming a positive attitude towards WeChat. Configuration H2 is the digital feedback under motivational synergy, including two autonomous motivations of PU and PE, as

well as CM and DF, all of which are core conditions. The perceived usefulness and enjoyment of WeChat by older adults are internal and external motivations (Davis, 1992). The widespread integration of digital technology in daily life such as travel, shopping, and healthcare compulsively controls the motivation of older adults to change their daily behavior patterns (Wu & Song, 2021). Therefore, autonomous motivation and controlled motivation have a synergistic effect. At the same time, DF from younger generations in terms of operations, values, and product parameters (Zhou & Ding, 2020) can enhance the positive attitude of older adults towards WeChat. For example, highly educated older individuals have a greater knowledge and thinking ability to perceive the value of WeChat more accurately, but the lag caused by aging limits their understanding of digital life (Xu et al., 2021). Therefore, in the process of using WeChat, older adults may lack sufficient personal judgment (Lu et al., 2009) and seek advice and help from their children.

Configuration of high AU. Configuration S1 is the motivational synergy type, including three autonomous motivations of PU, PEU, and PE, as well as CM as core conditions. The comprehensive perception of WeChat by older adults generates sufficient autonomous motivation. Meanwhile, convenient features such as online medical, online payment, and online ticket purchases may become controlling thresholds and obstacles in the daily life of older adults (Liu, Wu, et al., 2021; Department of Economic and Social Affairs, 2021; Seifert, Cotten, et al., 2021), so they make more effort to transform motivation into practical actions to accept WeChat. Configurations S2a and S2b are digital feedback under autonomous extrinsic motivation, with PEU and DF as core conditions and PU and PE as peripheral conditions. Due to psychological and physical constraints, ‘inability to use’ and ‘unknown how to use’ are major dilemmas that prevent older adults from enjoying digital life (General Office of the State Council of China, 2020). If older adults with good eyesight, hearing, and comprehension skills find WeChat easy to use, they face fewer obstacles related to ‘inability to use’. DF is an endogenous and continuous auxiliary that supports older adults in terms of technology, literacy, and values to overcome the challenge of ‘unknown how to use' (Zhou & Ding, 2020). Configuration S3 is digital feedback under motivational synergy, including two autonomous motivations (PU and PE) as well as CM and DF as core conditions. The usefulness and enjoyment perceived by older adults are autonomous intrinsic and extrinsic motivations

for adopting WeChat. The compulsive control of digital life popularization and support from DF in terms of operation, function, and digital literacy reduce the attitude of 'unwilling to use' and overcome obstacles of 'unknown how to use' (General Office of the State Council of China, 2020; Hjälm, 2012), leading to AU of WeChat.

The process from high ATU to high AU. In configuration H1, older adults have a positive attitude towards WeChat, but this configuration is not a sufficient condition for high AU. This configuration needs to increase CM or DF to cover configurations S1 and S2a, enabling older adults to accept WeChat through AU, where CM and DF have a substitute relationship. Configurations H2 and S3 are the same, which results in the ATU and AU of older adults in accepting WeChat being consistent. Configuration S2b of high AU cannot be directly transformed into a configuration of high ATU, indicating that high ATU among older adults towards WeChat is not a necessary condition for high AU.

Configuration of not-high ATU and not-high AU. There are three configurations of not-high ATU. First, configurations NH1a and NH1b indicate that if older adults lack PU and DF, even if they have high PE or high CM, they will not have a positive attitude towards using WeChat. Especially in NH1b, autonomous motivation and controlled motivation have antagonistic effects. Second, configuration NH2 indicates that older adults who lack PU, PEU, PE, and CM have negative attitudes towards WeChat. Meanwhile, configurations NH1a, NH1b, and NH2 all exhibit a lack of PU that prevents high ATU. This means that if older adults feel that digital technology cannot meet their daily convenience needs, it will be difficult for them to develop a positive attitude towards WeChat. There are three configurations of non-high AU. Configurations NS1, NS2, and NS3 all show that a lack of PEU hinders the generation of high AU. This means that if older adults feel that it is very difficult to use new media and technologies in digital life, they will experience psychological and physical barriers of 'inability to use', hindering their ability to enjoy digital life through AU.

4.2. Configuration analysis of urban-rural differences

The data for urban and rural areas were calibrated separately. The sufficiency analysis set the raw consistency threshold at 0.8, the PRI consistency threshold at 0.7, and the case frequency threshold at 2. The results of the configuration analysis are shown in Table 7. For urban older adults, there is one configuration with high ATU and two

configurations with high AU. The configuration consistency is above 0.8 and the solution consistency is above 0.9, which are sufficient conditions for the specific results. The solution coverage of the high ATU configuration is 0.755, explaining about 76 per cent of the reasons for high ATU. The solution coverage of the high AU configuration is 0.711, explaining about 71 per cent of the high AU. For rural older adults, there are 5 configurations with high ATU and 3 configurations with high AU. The configuration consistency is above 0.8 and the solution consistency is above 0.9, which are sufficient conditions for the specific results. The solution coverage of the high ATU configuration is 0.749, explaining about 75 per cent of the reasons for high ATU. The solution coverage of the high AU configuration is 0.707, explaining about 71 per cent of the high AU.

Table 7. Urban-rural differences in configurations

Condition	Urban			Rural							
	High ATU	High AU		High ATU					High AU		
	UH1	US1	US2	RH1a	RH1b	RH2	RH3a	RH3b	RS1	RS2a	RS2b
PU	●	●	●	●	●	●	●		●	●	
PEU	●	●	●	⊗		●	●	●	●	●	●
PE	●	●	●		●	●		●	●		●
CM		●		⊗	⊗		●	●		●	●
DF			●	●	●	●	●	●	●	●	●
Consistency	0.943	0.962	0.948	0.901	0.899	0.972	0.967	0.974	0.952	0.951	0.949
Raw Coverage	0.755	0.623	0.660	0.390	0.395	0.622	0.577	0.595	0.634	0.591	0.603
Unique Coverage	0.755	0.051	0.087	0.038	0.008	0.007	0.008	0.038	0.074	0.031	0.043
Solution Consistency	0.943	0.943				0.908				0.950	
Solution Coverage	0.755	0.711				0.749				0.707	

The configurations obtained in sufficiency Analysis are categorized and named as different mechanisms, and the results indicate that there are significant differences in the driving mechanisms for urban-rural older adults to adopt WeChat. (Figure 2)

	Urban	Rural
High AU	Motive synergy type (CS1); Digital feedback under autonomy-motivation(CS2)	Digital feedback under autonomy-motivation (VS1) ; Digital feedback under motivational synergy (VS2a, VS2b)
High ATU	Autonomy-motivation type (CH1)	Digital feedback under motivational antagonism (VH1a, VH1b); Digital feedback under autonomy-motivation (VH2); Digital feedback under motivational synergy (VH3a, VH3b)

Figure 2. Driving mechanism for urban-rural older adults to adopt WeChat

Urban-rural differences in high ATU configurations. The high ATU configuration for urban older adults is limited to the autonomy-motivation type (CH1), while rural older adults have three types of high ATU configurations: digital feedback under motivational antagonism (VH1a, VH1b), digital feedback under autonomy-motivation (VH2), and digital feedback under motivational synergy (VH3a, VH3b). Specifically, there are several urban-rural differences in the high ATU configurations: Firstly, urban older adults need to possess three types of autonomous motivation at the same time. Most rural older adults only need partial autonomous motivation, and the most important one is PU. This indicates that urban older adults initially had higher life satisfaction (Jiang et al., 2021). Therefore, their demands for WeChat are more extensive, with ease of use and enjoyment becoming important attractions. Rural older adults pay more attention to the usefulness of WeChat, and the main purpose is to increase the convenience of life through functions such as video calls and online payments. Secondly, urban older adults only need autonomous motivation, while some rural older adults develop a positive attitude through the synergy (VH3a, VH3b) or antagonism (VH1a, VH1b) of autonomous motivation and controlled motivation. Compared to urban older adults, rural older adults have lower levels of income, education, health, and other digital abilities and endowments (Jiang et al., 2021), making them more susceptible to the influence of CM. Meanwhile, the unbalanced and inadequate development of internet infrastructure and digital application scenarios in rural areas results in a significant gap in the level of CM among older adults (Liu & Wang, 2021). Thirdly, all high ATU configurations of rural older adults include DF. The poor physical health and education level of rural older adults have hindered their acceptance and comprehension (Jiang et al., 2021; Xu et al.,2023), leading to insufficient confidence in using WeChat and even technical anxiety. The DF provided by younger generations helps older adults overcome the psychological barrier of 'fear of difficulties' (Correa, 2013; Zhou & Ding, 2020).

Urban-rural differences in high AU configurations. The high AU configurations among urban older adults include the motivational synergy type (CS1) and the digital feedback under the autonomy-motivation (CS2). The high AU configurations for rural older adults include the digital feedback under autonomy-motivation (VS1) and the digital feedback under motivational synergy (VS2a, VS2b). Specifically, there are two urban-rural differences in the high AU configurations: On the one hand, in the high AU

configuration for urban older adults, only one of CM or DF needs to be added in addition to the three aspects of perception(CS1,CS2). However, two configurations (VS2a, VS2b) with high AU among rural older adults have both CM and DF as core conditions. This indicates that the ability of rural older adults to learn new things is relatively weak (Jiang et al., 2021). Faced with the rapid transformation and widespread application of WeChat, it is difficult to cross the skill threshold on one's own. Offsprings need to teach rural older adults how to operate and understand complex new functions. On the other hand, PEU as a core condition appears in all rural older adult's high AU configurations, which has crucial value in driving rural older adults to use WeChat. This once again proves that the lack of skills is an important reason hindering the WeChat adoption by rural older adults. It also indicates that the long-term low social security and medical health in rural areas have led to a decline in their physical conditions such as vision, hearing, and flexibility (Jiang et al., 2021), which limits their normal and smooth operation. Therefore, the issue of 'inability to use' among rural older adults requires significant attention.

Urban-rural differences in the process from psychology to behavior. The transformation from a high ATU configuration to a high AU configuration among urban older adults requires the addition of CM or DF. For rural older adults, some require the same conditions as high AU (VH2→VS1; VH3a→VS2a; VH3b→VS2b) during the high ATU stage, reflecting consistency in their attitude and behavior towards WeChat. As such, more effort should be invested in psychological construction. Another group of rural older adults needs to overcome the absence of PEU and CM (VH1a, VH1b) to transform their positive attitude towards AU. To bridge this gap, WeChat needs to continuously improve the simplicity and ease of operation, and quickly mitigate the urban-rural gap of digital conditions, thereby increasing the popularity of WeChat in rural areas. This also supports to some extent the research conclusion of Wu & Song (2021) and Lu et al. (2009) that CM can encourage some older adults to adopt digital technology. Regardless of whether urban older adults have a high ATU or a high AU, the coexistence of PU, PEU, and PE indicates that their comprehensive perception plays a key role in their attitude and behavior towards accepting WeChat. It is particularly important to reduce rejection among this group by updating and developing age-friendly digital technology in urban areas. DF is present in all high ATU and high AU configurations among rural older adults, indicating its importance in building their

information literacy and ability. It plays a fundamental, direct, and effective role in improving their skills, knowledge, and values in using new technologies and media (Correa, 2013; Zhou & Ding, 2020).

4.3. Robustness

To mitigate the concern for the robustness of the research results, we raised the threshold for the number of cases and consistency. If there are no substantial changes in the components, consistency, and coverage of the configuration, or if there is a clear subset relationship between configurations, the configuration result is considered reliable. When the consistency threshold was raised from 0.8 to 0.85, there were no substantial changes in the configuration, as shown in Table 8. Similarly, when the threshold for the number of cases was raised from 2 to 3, there were no substantial changes in the configuration, as shown in Table 9. Therefore, the antecedent configuration of the result is robust.

Table 8. Robustness test for increasing the consistency threshold

Condition	Urban			Rural						
	High ATU	High AU		High ATU				High AU		
	CH1	CS1	CS2	VH1	VH2	VH3a	VH3b	VS1	VS2a	VS2b
PU	●	⬤	●	⬤	⬤	⬤		⬤	⬤	
PEU	⬤	●	⬤	⊗	●	⬤	⬤	⬤	⬤	⬤
PE	⬤	⬤	●		●		●	●		●
CM		⬤		⊗		⬤	⬤		⬤	⬤
DF			⬤	●	●	⬤	⬤	●	⬤	⬤
Consistency	0.943	0.962	0.948	0.901	0.972	0.967	0.974	0.952	0.951	0.949
Raw Coverage	0.755	0.623	0.660	0.390	0.622	0.577	0.595	0.634	0.591	0.603
Unique Coverage	0.755	0.051	0.087	0.060	0.019	0.008	0.038	0.074	0.031	0.043
Solution Consistency	0.943	0.943			0.913				0.950	
Solution Coverage	0.755	0.711			0.741				0.707	

Table 9. Robustness test for increasing the threshold of the number of cases

Condition	Urban			Rural					
	High ATU	High AU		High ATU					High AU
	CH1	CS1	CS2	VH2	VH3a	VH3b	VS1	VS2a	VS2b
PU	●	●	●	⬤	⬤		⬤	⬤	
PEU	⬤	●	⬤	●	⬤	⬤	●	⬤	⬤
PE	⬤	⬤	⬤	●		●	●		●

CM		●			●	●		●	●
DF			●	●	●	●	●	●	●
Consistency	0.943	0.962	0.948	0.972	0.967	0.974	0.952	0.951	0.949
Raw Coverage	0.755	0.623	0.66	0.622	0.577	0.595	0.634	0.591	0.603
Unique Coverage	0.755	0.051	0.087	0.065	0.02	0.038	0.074	0.031	0.043
Solution Consistency	0.943	0.943			0.951			0.95	
Solution Coverage	0.755	0.71			0.68			0.707	

5. Discussion and implications

Configuration analysis shows that autonomous motivations are important conditions for older adults to develop a positive attitude towards WeChat, which is consistent with the conclusions of most related studies (Xu et al., 2023; X. Wang, 2023; Huang, 2023). However, in addition to this, some older adults (H2) also need the synergy of controlled and autonomous motivation, as well as the support of DF, indicating the significance of DTMIM. Regarding enhancing AU, C. Wang et al. (2023), Davis (1989), and Lu et al. (2009) have found a positive correlation between PEU and PU. However, PEU and PU in configurations S2b and S3 did not appear simultaneously. Although they discovered that the antecedents could interact, they did not uncover the complex mechanisms of complementarity or substitution. Meanwhile, previous studies have been controversial about whether PE can promote the adoption of digital technology among older adults (Davis, 1992; Lisha et al., 2017; Ramírez-Correa et al., 2019). Our research results provide a valuable explanation for the dilemma that most existing studies have analyzed the independent contribution of PE to the adoption of digital technology through linear analysis (Lu et al.,2009; Lisha et al., 2017; Xu et al.,2023). However, the adoption of new media and technologies is not solely due to the net effect of PE but rather due to the interaction of multiple conditions. Our research results show that PE is a core condition in configurations S1 and S3, and a peripheral condition in configurations S2a and S2b. This indicates that PE is crucial for high AU but must be complemented by other conditions. Significantly, studies have long found causal asymmetry between

ATU and AU. ATU can only explain part of AU (unnecessary) (Davis & Venkatesh, 1996), and there are contradictory facts of high ATU and low AU (insufficient) (Konca & Erden, 2021). However, follow-up research has only supplemented or modified the original TAM without analyzing the asymmetric causal mechanism between ATU and AU.

The analysis of urban-rural differences in configuration shows that urban older adults with a positive attitude towards WeChat require rich autonomy motivation, while rural older adults have concise autonomy motivation and need to interact with CM. This supports the SDT's view on the synergy or antagonism between autonomous motivation and controlled motivation (Ryan & Deci, 2019), and also mitigates the debate in existing research on the positive and negative effects of CM (Lu et al., 2009; Tandon et al., 2023; Wu and Song, 2021). Specifically, Ryan & Deci (2019) believe that CM can sometimes be internalized as autonomous motivation, promoting personal self-improvement and learning. However, sometimes CM is inconsistent with personal psychological needs, and actually cause anxiety and disgust towards WeChat among older adults, weakening autonomous motivation. DF plays a crucial role in the adoption of digital technology among older adults, aligning with previous research findings. However, these studies have not paid enough attention to the urban-rural differences (Song et al., 2021; C. H. Wang & Wu, 2022). Compared to urban older adults, all configurations of ATU and AU for rural older adults have DF. The ‘empowerment’ of digital technology in social participation and life satisfaction is limited to older adults with digital literacy and abilities (C.H. Wang & Wu, 2022), and this gap is particularly prominent between urban and rural (Liu & Wang, 2021). Without emotional or technological support from their offspring, digital inequality and the generational gap of rural older adults will worsen. There are significant urban-rural differences in the

transition from psychology to behavior. Rural older adults need to overcome the absence of autonomous and controlled motivation. The positive psychology and behavior of urban older adults adopting WeChat require the coexistence of three autonomous motivations (PU, PEU, and PE). This is similar to the research conclusion of Lisha et al. (2017), which suggests that autonomous motivations can mutually enhance each other, manifested as a synergistic effect between autonomous internal motivation and autonomous external motivation.

5.1. Theoretical contributions

In addressing the limitations of TAM's insufficient adaptability to 'digital exclusion' and back-feeding culture, we developed DTMIM combining SDT and DFT. On the one hand, we aimed to address the core contradictions caused by the weak psychological and physical conditions of older adults and the popularization of digital applications by introducing CM into TAM based on SDT (Seifert, Cotten, et al., 2021; Song et al., 2021). SDT believes that self-integration, self-improvement, and learning tendencies need are built on the organic interaction between people and the environment (Ryan & Deci, 2019). Motivations include not only autonomous motivation but also CM generated from external conditions or internal psychological compulsion (Ryan & Deci, 2000). This provides a theoretical basis for elucidating the observable phenomenon wherein the proliferation of digital technology compels older adults to embrace digital lifestyles. On the other hand, in back-feeding culture (Song et al., 2021), we introduced DF into TAM as an endogenous and continuous auxiliary force (Zhou & Ding, 2020; Wright, 2000; Liu, Wu, et al., 2021). DTMIM is an adaptive improvement of TAM in scenarios of 'digital exclusion' and back-feeding culture. We propose an innovative theoretical framework for studying how older adults can enjoy digital life.

We analyzed the antagonistic or synergistic effects of multiple conditions on older adults' acceptance of new media and technologies from a configurational perspective, explaining the complex causal mechanism. The WeChat adoption among older adults is a complex psychological and behavioral process (Taipale et al.， 2021). Most previous studies have focused on analyzing the 'net effect' of variables, which is not conducive to discovering differences in specific outcomes between different subgroups and may

lead to conflicting research results (Lisha et al., 2017; Huang, 2023). This resonates with Venkatesh's reflection on 'the lack of combined effects between conditions in the UTAUT.' Through fsQCA, we found that various conditions in DTMIM drive older adults to accept WeChat with inter-dependence, combination effect, and multiple conjunctural causation. This represents a theoretical contribution combining configuration theory and TAM, providing a new paradigm for studying users' technology adoption.

Our analysis of urban-rural differences in configuration provides a theoretical reference for more detailed analysis of older adults' adoption of digital technology. Extant studies have primarily focused on analyzing technology acceptance among urban older adults, with insufficient attention paid to rural older adults, particularly regarding urban-rural differences in their acceptance of digital technology (Liu, Wu, et al., 2021; Song et al., 2021). We analyzed configurations for these two samples separately and found significant urban-rural differences in the mechanism for older adults to accept WeChat. This provides a theoretical basis for constructing solutions that combine universal adaptation with classified advancement.

5.2. Practical implications

The configuration analysis of DTMIM will provide evidence for building a governance system for the 'digital divide'. The WeChat adoption among older adults is influenced by the interaction of many factors, so we must shift from a single focus on local optimization to a systematic approach to configuration coordination. The government, WeChat, and family should work together to help older adults embrace digital life. However, it is difficult and not necessary to meet all requirements for older adults with different characteristics. For older adults with different age groups, educational, living environments, and habits, problems should be classified and sorted out, and personalized and differentiated solutions should be adopted. Among them, PE is a unique factor that drives all older adults to adopt WeChat. WeChat can develop entertainment programs or functions that are simple in process and easy to operate according to the special needs of older adults, such as functions suitable for the general needs of square dancing, mass singing, etc.

The analysis of ATU and AU configuration can provide decision-making basis for helping older adults at different stages adopt WeChat. For older adults with low ATU

and low AU. On the one hand, the government's age-appropriate construction should appropriately retain traditional service methods, especially offline service channels in high-frequency services such as public transportation, healthcare, social security, and bank. Reasonably equip guidance staff and on-site reception windows, ensuring that older adults who cannot accept WeChat can also enjoy basic public services. On the other hand, the government and WeChat collaborate to mobilize their positive attitude, especially to enhance PU. For example, enterprises actively participate in supplying internet products and services suitable for older adults, while the government increases promotion about digital technologies can improve their quality of life. For older adults with high ATU, certain conditions should be added or strengthened to encourage them to transform positive ATU into AU. Particular attention should be paid to the general hindrance to AU due to lack of PEU. The decline of physical functions such as hearing and vision hinders that older adults use digital technology. WeChat should strengthen its age-appropriate transformation, improve easiness through content reading, voice assistance, and 'older adults mode'. For older adults with high AU, whole society should provide digital knowledge training and education for them. For example, gerontological universities and gerontological societies should regularly conduct digital life-themed activities.

The analysis of urban-rural differences in configuration will provide targeted and adaptive solutions for addressing digital inequality between urban and rural areas. Targeted and differentiated solutions for urban and rural older adults should be implemented respectively. For urban older adults, the focus is on improving PU, PEU, and PE to cultivate subjective initiative. Community and family members should highlight the dominant position of older adults, emphasize their own enthusiasm and initiative, advocate and stimulate the positive attitude of urban older adults to actively learn information technology and adapt to digital society, helping them embrace a comfortable and convenient digital life. For rural older adults, their children and grandchildren should help them to overcome technical and cognitive barriers and frequently through DF to improve new media literacy and adaptability to digital life by helping their overcome technical and cognitive barriers. Meanwhile, the government and society should actively promote a cultural atmosphere that encourages younger generations to provide DF for rural older adults.

6. Limitations and future studies

Although our study has new findings, there are some limitations. On the one hand, we only analyze the urban-rural differences in configurations because we recognize that urban-rural dual structure exacerbates digital inequality among older adults (Liu & Wang, 2021; Lu et al., 2023), and there is an urgent need to provide a basis for alleviating digital inequality through comparative analysis. However, there are also differences in digital abilities and endowments among older adults of different educational backgrounds, ages, and genders (Liu, Wu, et al., 2021; Song et al., 2021; Xu et al.,2023). Future research can compare the differences in mechanisms that drive older adults to use WeChat based on these characteristics. On the other hand, we find that DF plays an important role in the adoption of WeChat among older adults, especially in rural areas. Previous articles have divided DF into object feedback, skill feedback, and literacy feedback (Zhou & Ding, 2020; C. H. Wang & Wu, 2022). However, this study only found that DF as a whole is an external supporting construct and did not reveal the specific effects of different dimensions of DF. Future research can further analyze how different dimensions of DF and motivation can interact to cultivate positive attitudes and behaviors towards WeChat, improving the granularity and explanatory power of DTMIM.

7. Conclusions

In order to reveal the driving mechanism for urban-rural older adults to adopt WeChat, we analyzed DTMIM using fsQCA, and the results are as follows: (1) None of the five conditions alone can constitute necessary conditions for high ATU (non-high ATU) or high AU (non-high AU). (2) Two configurations trigger high ATU: autonomy-motivation type and digital feedback under motivational synergy. Three configurations trigger high AU: motivational synergy type, digital feedback under autonomous extrinsic motivation, and digital feedback under motivational synergy. These multiple configurations demonstrate the characteristics of multiple conjunctural causation and equifinality for older adults with different characteristics. (3) The analysis of the process from psychology to behavior reveals the causal asymmetric mechanism between high ATU and high AU for WeChat among older adults. (4) There are significant urban-rural differences in both high ATU and high AU configurations. The three autonomous

motivations are key conditions for urban older adults to adopt WeChat, while DF is particularly important in the configuration of rural older adults.

Disclosure statement:

No potential conflict of interest was reported by the author(s).

Funding:

This work was supported by National Natural Science Foundation of China (NSFC) (no.72274164, no.71872160, no.72064043, no.72362034); Scientific Research Fund Project of Yunnan Provincial Department of Education (no.2023Y0617, no.2024Y527). Scientific Research Fund Project of Yunnan University of Finance and Economics (no. 2022D03).

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Appendix A. Measurement instrument used in the questionnaire

Constructs	Coding	Items	References
Perceived usefulness	PU1	Using WeChat can make my daily life more convenient	Davis et al.,1989; Lisha et al., 2017
	PU2	Use WeChat enables me to accomplish tasks more quickly	
	PU3	Overall, use WeChat is useful for my job or daily life	
Perceived Ease of Use	PEU1	Learning to use WeChat is easy for me	Davis et al.,1989; Lisha et al., 2017
	PEU2	My interaction with WeChat is clear and understandable	
	PEU3	I find WeChat easy to use.	
	PEU4	It would be easy for me to become skillful at using WeChat	
Perceived Enjoyment	PE1	Using WeChat gives me pleasure.	Davis et al., 1992; Lisha et al., 2017
	PE2	Using WeChat is fun.	
	PE3	Using WeChat makes me happy.	
	PE4	In short, I think Wechat is very interesting.	
Controlled Motivation	CM1	I will have a lot of trouble if I don't use WeChat	Ryan and Connell., 1989
	CM2	I use WeChat because I don't want people around me to think I'm lagging behind	
	CM3	I will feel very ashamed if I don't use WeChat	
	CM4	I use WeChat hoping that people around me will think I am capable	
Digital Feedback	DF1	My children or grandchildren will actively guide me in using WeChat and help me solve usage issues	Correa, 2013; Zhou and Ding, 2020
	DF2	I usually seek help from my children or grandchildren if I encounter some problems while using WeChat	
	DF3	My children or grandchildren encourage me to use WeChat	
	DF4	My children or grandchildren often share with me the new functions and information of WeChat	
	DF5	My children or grandchildren often talk to me about the importance of WeChat	
	DF6	The first time using WeChat was recommended by children or grandchildren	
Attitude Toward Using	ATU1	I think WeChat is very worthwhile to use	Davis et al.,1989; Kim et al., 2016
	ATU2	I am very willing to use WeChat	
	ATU3	I think WeChat is very helpful for my life	
	ATU4	My evaluation of WeChat is very positive	
Actual Using	AU1	I often use WeChat	Davis et al.,1989; Hagger et al., 2007
	AU2	I spend a lot of time using WeChat every day	
	AU3	I will continue to use WeChat in the future	
	AU4	I often recommend my friends to use WeChat	