How does the Internet use shape the age identity among Chinese older adults?

Ke Shen[a], Huilin Sun[b*]

([a]. School of Social Development and Public Policy, Fudan University, Shanghai 200433, China;

[b]. School of Social Development and Public Policy, Fudan University, Shanghai 200433, China)

Abstract

Based on the panel data from 2018 and 2020 waves of China Longitudinal Aging Social Survey, the study employs the fixed-effects models to examine whether and how Internet use influences age identity of older adults. The results show that Internet use contributes to a younger age identity measured by perceived old age, felt age, or appearance age. The benefits of Internet use vary by the frequency and purpose of use. Daily users hold a much younger age identity than non-users. Online communication and entertainment are beneficial for age identity, while no such effect is observed for online life services. We further reveal that Internet use enables older adults to improve participation in offline social activities, to promote their social adaptation, and also to reduce the likelihood of feeling worthless, thus leading to a positive perception of aging. Moreover, the benefits of Internet use are more pronounced for female, younger, urban, and better-educated older adults. Our study has established the Internet as a valuable resource for successful aging. In the process of constructing Digital China, it is crucial to bridge the digital divide by designing age-friendly digital products and also to enhance older adults' digital literacy.

Keywords: Internet use; Age identity; Social participation; Social adaptation; Fixed-effects instrumental variable estimation

1 Introduction

China is in the middle of a highly compressed population aging process which is unparalleled globally, due to its extraordinary decline in birth rate and extension in life expectancy over the past

* Corresponding author. Email: hlsun22@m.fudan.edu.cn (H. Sun.)

half century. The older adults aged 65+ as a share of the total population in China rose precipitously from 7 percent in 2000 to above 14 percent in 2021, marking a transition from an aging society to an aged society. In the coming decade, as the baby boomers born in the mid-1960s are about to approach old age, and the recent number of births has reached a historic low, China's population will be aging at an even faster pace. In just thirteen years, by 2034, the share of older adults aged 65+ is expected to surpass 21 percent, the threshold for a super-aged society (United Nations, 2022).

In rapidly aging societies, chronological age is conventionally used in constructing welfare systems, revising retirement policy, and distributing public resources for the elderly. However, it is notable that older adults experience age identities that are often distinct from their chronological ages (Alonso-Debreczeni and Bailey, 2021; Kleinspehn-Ammerlahn et al., 2008), and any categorization of chronological age obscures the physiological, psychological, and social diversity of older people (Bowling et al., 2005). Even after accounting for chronological age and previous health conditions, maintaining a youth identity is associated with improved physical and mental health, better life satisfaction and longer life expectancy (Levy et al., 2002; Keyes and Westerhof, 2012; Alonso-Debreczeni and Bailey, 2021), which in turn encourages the older adults to contribute to both society and family (Maalaoui et al., 2023; Yu and Wang, 2023). By contrast, feeling old may lead to impaired cognition, loneliness, and depression (Carp and Carp, 1981; Kavirajan et al., 2011; Freeman et al., 2016; Jose and Cherayi, 2017). Therefore, age identity is not only a crucial predictor of successful aging, but also operates as a refined indicator for the construction of age-related policies.

Among the various social, economic, and behavioral factors that may influence the age identity of older adults, the widespread use of Internet is particularly noteworthy as it has brought fundamental changes to people's lives. On the positive side, the Internet could facilitate access to information, expand opportunities for social participation, and increase social connectedness for older adults (Heo et al., 2015; Sun and Zhou, 2021), which in turn results in a younger subjective age (Zhao et al., 2024). However, on the negative side, online surfing might undermine offline activities and reduce social interaction (Benvenuti et. al., 2020; Meshi et al., 2020). Senior netizens may also feel less capable of adapting to the digital environments when they repeatedly encounter problems in complicated online tasks such as banking and healthcare appointments (Ranchordás, 2020), leading to a negative attitude toward aging.

China offers a crucial setting for studying the relationship between Internet usage and age

identity, as China's digital revolution coincides with its rapid population aging process. The number of Internet users rose exponentially from 22.5 million in 2000 to 1.08 billion in 2023. The share of the population using the Internet rose from 1.8 percent to 76.4 percent over the same period. The rise in Internet adoption among older adults is even more remarkable. As shown in Figure 1, in 2000, older netizens aged 60+ only represented 1.26 percent of all Chinese Internet users, making age a central predictor of digital exclusion. By 2023, the proportion of older netizens has reached 13 percent, and over one-half of older adults have mastered at least one digital skill, in sharp contrast with merely 0.6 percent back in 2005. Therefore, it is worth investigating whether older adults could reap the benefits of digital transformation by holding a more youthful identity.

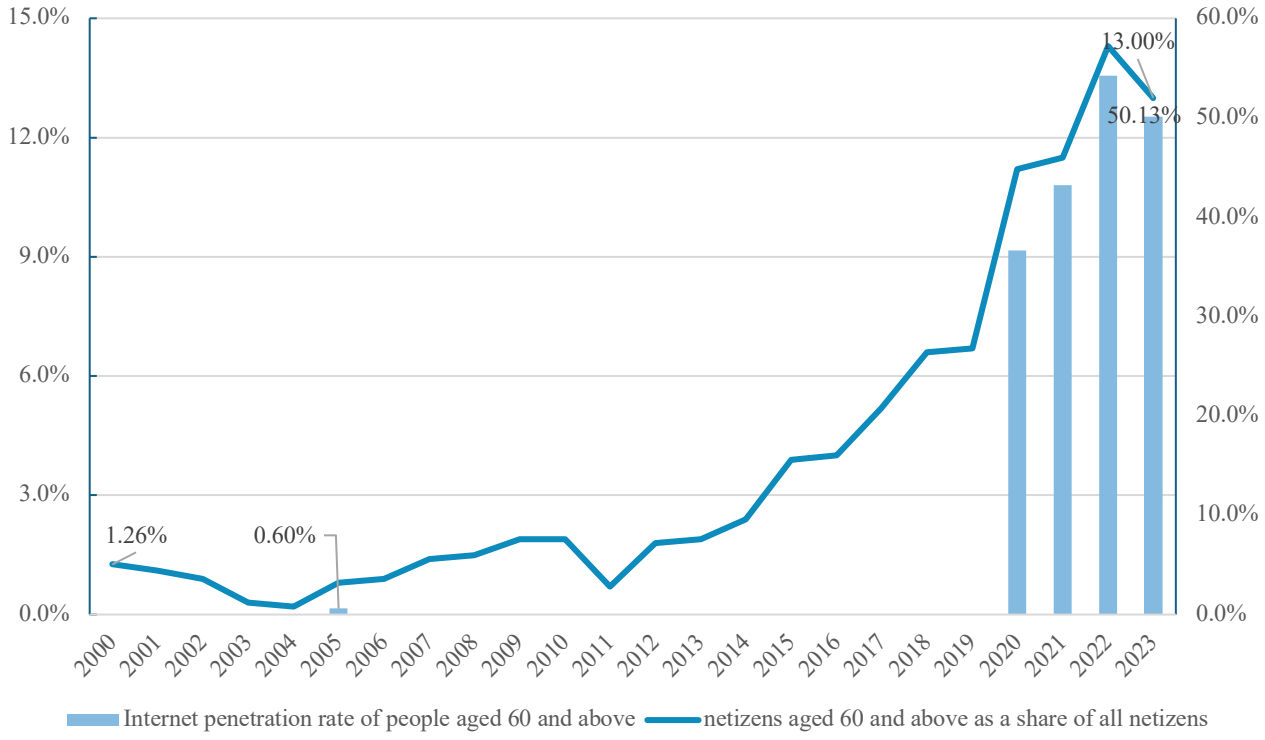

Figure 1. Internet usage of people aged 60+, 2000-2023.

Data resource: China Internet Network Information Center

Note: For netizens aged 60+ as a share of all netizens, the data for 2023 is acquired in June 2023, while other years report the data of December in that year. Internet penetration rate of people aged 60+ is only available for 2005, 2020, 2021, 2022 and 2023.

Based on the panel data from the latest 2018 and 2020 waves of China Longitudinal Aging Social Survey (CLASS), we examine whether and how the use of Internet impacts age identity among older adults, and then proceed to investigate how the impacts vary across sociodemographic groups. Our

study makes three marginal contributions to the relevant literature. First, as a majority of older adults start using the Internet for communication and information retrieval, it is important to go beyond studying whether being an Internet user makes a difference. We thus consider a more nuanced view of Internet use by including the frequency of Internet use and types of online activities. Second, we extend the analysis of the mechanisms through which Internet use exerts an influence on age identity, including social participation, social adaptation and also feeling of worthlessness. Third, we comprehensively examine the heterogeneity in the impacts of Internet use by gender, age group, urban-rural residence, and education, with the assumption that the more privileged groups may be more capable of leveraging digital technology. Fourth, the causal impact of Internet use on age identity might be biased due to reverse causality, which means that older adults who view themselves younger are more likely to use Internet. Therefore, we apply the fixed effects instrumental variables (IV) estimation to address the potential endogeneity concern and check the robustness of baseline estimates.

The rest of the paper proceeds as follows. Section 2 provides an overview of the literature on the effects of Internet use on age identity. Section 3 describes the empirical strategy, data source, and variable construction. Section 4 presents the empirical results, including baseline regression, robustness check, mediation analysis, and heterogeneity analysis. We conclude the research in Section 5.

2 Literature review

Age identity, or self-perceived age, is defined as the subjective evaluation of a person's age (Kaufman and Elde-Jr, 2002; Bowling et al., 2005). Age identity is a multidimensional construct, encompassing several related but distinct concepts, such as perceived old age, felt age, and appearance age (Bordone et al., 2020). Perceived old age is a reflection of one's perceived standard for being old, assessed by asking a person the question "*At which age do you think old age starts*?" (Kaufman and Elde-Jr, 2002). Felt age or subjective age refers to the age an individual feels like or views him or herself, evaluated by the question "*How old do you feel?*" (Barrett, 2003). Appearance age or look age is measured by asking "*How old do you think you look?*" (Kastenbaum et al., 1972), and those who repeatedly hear that they look young might adjust their appearance age accordingly

(Kotter-Gruhn and Hess, 2012)

A large body of studies has revealed a discrepancy between chronological age and age identity (Alonso-Debreczeni and Bailey, 2021; Kleinspehn-Ammerlahn et al., 2008). Such a discrepancy is influenced by older adults' social roles, socioeconomic status, social experiences, and cultural age norms (Barrett, 2003; Diehl et al., 2014; Shanahan and Elder, 2002). Among these factors, how Internet use influences the age identity of older adults remains underexplored and merits further investigation. This topic relates to a broader stream of literature on the impact of Internet use on subjective well-being, which has produced mixed findings. A series of studies have elaborated on the benefits of Internet use for older adults through multiple channels (Chopik, 2016; Zhou et al., 2023). First, the wide variety of services and information available on the Internet acts as a major gateway for social and community participation (Sims et al., 2017). Second, Internet use enhances interpersonal communication (especially over long distances) and expands social networks, which can promote social adaptation and reduce social isolation for older adults (Du and Luo, 2023; Chen, 2020; Yu and Fiebig, 2020). Third, Internet helps maintain functioning and independence, and also motivates engagement with important life goals, particularly for those faced with old-age limitations such as restricted mobility and sensory impairment (Schulz et al., 2015), thus making older adults less likely to feel worthless and falling behind the times.

Conversely, some studies show that Internet use is unrelated or even detrimental to subjective well-being (Slegers et al., 2008; Nie et al., 2017). Internet might pull older people's interests away from their local area, weaken community ties, and lower the sense of belonging to a community (Kraut et al., 1998; Hage et al., 2016; He and Yan, 2022), thereby reducing their participation in volunteering, public affairs, and other community-based activities. Moreover, heavy Internet use might displace face-to-face contacts and reduce real-life social support, leading to lower social adaptation and increased social isolation (Meshi et al., 2020; Sun and Zhou, 2021). Last but not least, the lack of digital skills might make the older netizens less capable of managing the increasing digitalization of modern societies (Ranchordás, 2020), thus intensifying their feelings of worthlessness.

Some studies further revealed different purposes of Internet use could lead to various results for subjective well-being. Based on the sample of Australian older adults, Sum et al. (2008) showed that Internet use for multiple purposes such as information-seeking, communication, and entertainment

was associated with reduced social loneliness, while online chatting with strangers exerted a negative impact on their interaction with family members. Evidence from the US confirmed the positive effects of online information-seeking and entertainment on older adults' social engagement, but no such effect was detected for online communication (Ihm and Hsieh, 2015). Yang et al. (2022) found that online communication and entertainment significantly alleviated depressive symptoms for Chinese older adults, while online working and study did not show such a protective effect.

Prior studies have also identified the heterogenous impacts of Internet use on the subjective well-being by sociodemographic groups. For instance, based on the data from English Longitudinal Study of Ageing (ELSA), Lam et al. (2020) found that frequent Internet usage exerted a more prominent positive impact on mental health among the better-educated group. Evidences from China showed that the younger, female, urban, and better-educated elderly benefited more from Internet use (Yang et al., 2022; Du and Luo, 2023; Ni and Wang, 2023).

Little research has directly unveiled the relationship between Internet use and age identity of older adults. Drawing on the data from Health and Retirement Study, Wang and Gu (2023) revealed that Internet use promoted the self-perception of aging in the US. The study by Zhao et al. (2024) is the first to explore the impact of Internet use on subjective age and the underlying mechanisms in the context of China. They found that compared with moderate users, nonusers reported a significantly older subjective age, whereas the differences between moderate and heavy users were not significant. Such a positive link between Internet use and subjective age was partially explained by stronger feelings of being valued, while the mediating role of increased participation in volunteering was not confirmed. In their study, Internet use frequency was constructed based on self-reported responses (never, occasionally, sometimes, frequently, or always), and thus a more objective measure of use frequency would be helpful to reappraise the findings. Moreover, it is important to examine how various purposes of Internet use (e.g. for communication, entertainment, or life services) affect age identity differently. Third, the underlying pathways linking Internet use and age identity could be expanded by including more mediators such as social participation, social adaptation, and feeling of worthlessness. Last but not least, the investigation of heterogeneity in the impacts of Internet use by sociodemographic groups would be informative for more targeted policy-making.

3 Methodology, data, and variables

3.1 Empirical strategy

To investigate the relationship between Internet use and age identity, we utilize the fixed-effects models:

$$age\_identity_{it} = \beta_0 + \beta_1 Internet_{it} + \beta_2 X_{it} + \lambda_t + \mu_i + \varepsilon_{it} \ (1) \ ,$$

where $age\_identity_{it}$ denotes the age identity of individual i in year t; $Internet_{it}$ refers to Internet use variables; X_{it} represents control variables. β_0 is a constant term, β_1 and β_2 indicate the coefficients of corresponding variables. λ_t and μ_i capture the time and individual fixed effects respectively. ε_{it} is random error.

It is noted that Internet use might be endogenous due to reverse causality, namely, the elderly who feel younger are more likely to surf the Internet (Seifert and Wahl, 2018). To address the potential endogeneity bias, we employ the fixed-effects instrumental variables (IV) estimation using two-stage least square (2SLS) models for robustness check.

$$Internet_{it} = \theta_0 + \theta_1 IV_{it} + \theta_2 X_{it} + \pi_t + \nu_i + \epsilon_{it} \ (2)$$

$$age\_identity_{it} = \phi_0 + \phi_1 Internet_{it} + \phi_2 X_{it} + \omega_t + \rho_i + o_{it} \ (3),$$

where IV_{it} refers to the instrumental variable, and the other variables are the same as Equation (1). F-statistic in the first-stage regression is reported to test whether the instrument is weak, as weak instruments might produce biased IV estimators in small samples.

If we find internet use significantly impacts age identity, we then proceed to examine the underlying mechanisms using two-stage mediation models:

$$Mediator_{it} = \alpha_0 + \alpha_1 Internet_{it} + \alpha_2 X_{it} + \varphi_t + \delta_i + \xi_{it} \ (4)$$

$$age\_identity_{it} = \gamma_0 + \gamma_1 Internet_{it} + \gamma_2 Mediator_{it} + \gamma_3 X_{it} + \sigma_t + \tau_i + \eta_{it} \ (5),$$

where $Mediator_{it}$ represents the mediating variables. If both α_1 and γ_2 are significant, it confirms the mediating role of $Mediator_{it}$ on the relationship between Internet use and age identity. If γ_1 is no longer significant, it suggests a complete mediating effect. if γ_1 is diminished but remains significant, it suggests a partial mediating effect, with the contribution rate being $(\alpha_1 * \gamma_2)/(\alpha_1 * \gamma_2 + \gamma_1)$ (Judd and Kenny, 1981; Baron and Kenny, 1986).

3.2 Data and variables

The data come from China Longitudinal Aging Social Survey (CLASS), a large-scale nationwide social survey directed by National Survey Research Center at Renmin University of China. It targets older adults aged 60 and over, collecting rich information on their sociodemographic characteristics, age identity, health status and lifestyles, social participation, and social adaptation. It covers 462 rural villages and urban communities in 134 counties of 28 provinces (excluding Hainan, Xinjiang, Tibet, Hong Kong, Macao, and Taiwan) in China. The baseline survey was conducted in 2014, with three follow-up waves carried out in 2016, 2018, and 2020.

As the 2018 and 2020 survey design the same questions on Internet use, our study is based on the panel data from these two waves to ensure consistency. After excluding observations with missing values and measurement errors for key variables, we got a final sample of 10920 observations for 5460 respondents.

Outcome variable. Age identity is measured based on three questions "*At what age do you think you become old?*" (perceived old age), "*Most of the time, how old do you feel?*" (felt age), and "*Most of the time, how old do you think you look?*" (appearance age). Respondents were allowed to give any age (in years) for each of the questions. The first variable of age identity is the discrepancy between their perceived old age and chronological age. The larger the difference is, the more years from now the respondent considers him/herself to become old. The second is a binary variable by comparing a respondent's perceived old age with their chronological age. It takes the value of one if a respondent's chronological age is younger than the perceived old age, and otherwise, it is zero. As shown in Table 1, 44 percent of the respondents over the chronological age of 60 think they have not turned old yet. The third variable is calculated by subtracting felt age from chronological age. As shown in Table 1, the older respondents feel 2.8 years younger than they actually are on average. The fourth variable captures the discrepancy between the chronological age and appearance age, the average of which also stays positive. For all of these four variables, higher values suggest that the older respondents hold a more youthful identity. It is also noted that the standard deviation of the first age identity variable is about twice as large as that of the third and fourth variables, suggesting a greater variation in the age at which the older respondent believes he or she becomes old.

Key Independent Variable. Internet use is measured by a series of indicators, including being

netizens, frequency of Internet use, and type of Internet activities. The first variable is whether the respondent uses Internet. The second variable, frequency of Internet use is constructed based on the question "*How often do you surf the Internet*", with five responses "*Every day*", "*At least once a week*", "*At least once a month*" "*A few times a year*" and "*Never*". The responses are grouped into three categories: daily users (those who use Internet every day), non-daily users, and nonusers. As shown in Table 1, about one-quarter of the respondents are netizens, and among them, 76 percent are daily users and 24 percent are non-daily users. The type of Internet activities is measured by the multiple-choice question "*What do you often do online*" with 11 options. Three binary variables are constructed based on the responses: whether the respondent often uses Internet for communication (voice chat, video chat, and text chat), for entertainment (browsing news, seeking information, listening to music, watching videos, and playing games), and for life services (shopping, transportation, health management, financial service, and study and training) (Du and Luo, 2023). As shown in Table 1, online communication is most frequently used, followed by online entertainment and then online life services. An alternative indicator of the type of Internet activities is to sum the responses, with higher values indicating more diversified use of Internet.

Instrumental variable (IV). We choose two alternative IVs for Internet use. The first IV is the legal entities[1] in the information transmission, software, and IT service industry as a share of all legal entities at the provincial level, based on data from China Statistical Yearbooks. This instrument, serving as a proxy for local IT development, facilitates older adults to use Internet and does not have a direct effect on their perception of aging, which satisfies the two criteria for a reliable instrument. The second is the share of netzines among all respondents at the prefecture-level cities, estimated from the CLASS data. The Internet adoption among older cohorts in the local area would affect the respondent's use of Internet through peer effects (Shi et al., 2023), while have no direct effect on their age identity.

Mediating variable. Social participation, social adaptation, and feeling of worthlessness are hypothesized to explain the association between Internet use and age identity. Social participation is measured by the respondent's participation in volunteering, public affairs, and recreational activities. CLASS questionnaire lists eight types of volunteer activities including community patrol, caring for

[1] Legal entities include enterprises, public institutions, government departments and non-governmental organizations.

non-relative older adults, environmental and hygiene protection, mediating disputes, companion and chatting, professional services such as free medical counseling, caring for non-relative children, and others. If the respondent has been engaged in any of these activities in the past year, participation in volunteering is coded as one. Participation in public affairs is measured by the question "*Have you voted in the elections of community or village committees in the past three years?*". It takes the value of one if the answer is "*Yes*", and otherwise it is zero. Participation in recreational activities is measured by whether the respondent has been engaged in mahjong, chess, cards, or square dance in the past year. Social adaption is measured by the Social Adaptation Scale with eight items. The responses to eight items are summed and standardized, with higher values suggesting better social adaptation (Chen, 2008). Feeling of worthlessness is measured by asking "*Have you ever felt that you were useless in the past week?*". If the respondent has ever felt useless in the past week, it is coded as one, and otherwise, it is zero.

Control variable. A series of variables that may affect the age identity are adjusted for, including age, gender, literacy, religion, marital status, hukou status, urban-rural residence, living arrangement, self-reported health, chronic disease, income, and pension entitlement.

Table 1. Definitions and descriptive statistics of main variables.

Variable	Definition	Obs.	Mean	Std. Dev.	Min	Max
Independent Variable						
netizen	1=use Internet, 0=nonuser	10920	0.234	0.423	0	1
frequency of use						
daily user	1=daily user, 0=nonuser	10920	0.178	0.382	0	1
non-daily user	1= non-daily user, 0=nonuser	10920	0.071	0.257	0	1
communication	1=use of Internet for communication, or else 0	10920	0.228	0.419	0	1
entertainment	1=use of Internet for entertainment, or else 0	10920	0.208	0.406	0	1
life services	1=use of Internet for life services, or else 0	10920	0.073	0.260	0	1
type score	sum of types of online activities	10920	0.508	0.947	0	3
Dependent Variable						
age identity1	perceived old age - chronological age	10920	-0.008	12.228	-38	53
age identity2	1=(perceived old age>chronological age), or else 0	10920	0.444	0.497	0	1
age identity3	chronological age - felt age	10073	2.804	6.572	-32	45
age identity4	chronological age - appearance age	10030	2.643	6.125	-33	45
Instrument Variable						
IV1	the proportion of legal entities in information transmission, software, and information technology service industry to all the legal entities at provincial level (%)	10920	4.264	1.079	1.495	7.803

IV2	Internet penetration rate of elderly respondents in the prefecture (%)	10920	23.535	21.874	0.000	74.294
Mediating Variable						
volunteer	1=participation in volunteering, or else 0	10920	0.573	0.495	0	1
public affairs	1=participation in public affairs, or else 0	10920	0.452	0.498	0	1
recreation	1=participation in recreational activities, or else 0	10920	0.368	0.482	0	1
social adaptation	social adaptation score	10920	0.000	1.000	-3.766	3.796
feeling of worthlessness	1= ever feel useless, 0=never	10920	0.554	0.497	0	1
Control Variable						
age	chronological age in years	10920	70.680	6.308	60	98
male	1=male, 0=female	10920	0.513	0.500	0	1
literate	1=literate, 0=illiterate	10920	0.770	0.421	0	1
religious	1=religious, 0=not religious	10920	0.059	0.235	0	1
married	1=married, 0=single/widowed/divorced	10920	0.740	0.439	0	1
urban hukou	1= non-agricultural, 0=agricultural	10920	0.509	0.500	0	1
urban residence	1=urban, 0=rural	10920	0.595	0.491	0	1
living alone	1=live alone, or else 0	10920	0.105	0.307	0	1
self-reported health	1 = very unhealthy, 2 = relatively unhealthy, 3 = fair, 4 = relatively healthy, 5 = very healthy	10920	3.402	0.851	1	5
disease	1= with chronic diseases, or else 0	10920	0.791	0.407	0	1
income	ln(respondent's annual income+1)	10920	9.398	1.588	0.000	11.513
pension	1=pensioner, 0=non-pensioner	10920	0.793	0.405	0	1

4 Empirical results

4.1 Baseline Regression

We start by examining the impacts of Internet use on age identity measured by the difference between perceived old age and actual age. As shown in Table 2, Model 1 suggests that Internet use is positively related to age identity. More specifically, Internet users would raise their perceived standard for being old by 1.82 years as compared with non-users. Model 2 further shows that use frequency matters for perceived old age. Non-daily Internet users are not different from nonusers in terms of age identity, while daily users maintain a significantly more youthful identity. Model 3-5 display the differential impacts of various types of online activities. Individuals who often use Internet for communication and entertainment perceive the age at which they become old 2.07 and 0.98 years later, while use of Internet for life services have no significant impact on the perception of transition to old age. Model 6 reveals that the more diversified online activities the older adults engage in, the later age of onset of aging they perceive.

As for control variables, younger, unmarried, urban, and religious respondents tend to perceive themselves younger. Good self-reported health, free of chronic disease and eligibility for pension also contribute to positive attitudes toward ageing.

Table 2. Baseline regressions of Internet use on age identity.

	(1) age identity1	(2) age identity1	(3) age identity1	(4) age identity1	(5) age identity1	(6) age identity1
netizen	1.819***					
	(0.000)					
frequency of use						
daily user		2.115***				
		(0.000)				
non-daily user		1.177				
		(0.116)				
communication			2.065***			
			(0.000)			
entertainment				0.983**		
				(0.047)		
life services					-0.349	
					(0.579)	
type score						0.523**
						(0.017)
age	-1.212**	-1.223**	-1.205**	-1.230**	-1.252**	-1.227**
	(0.013)	(0.013)	(0.013)	(0.012)	(0.011)	(0.012)
religious	2.185***	2.155***	2.201***	2.195***	2.128***	2.189***
	(0.003)	(0.003)	(0.002)	(0.003)	(0.004)	(0.003)
married	-1.699***	-1.696***	-1.700***	-1.726***	-1.777***	-1.713***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
urban hukou	0.130	0.187	0.068	-0.184	-0.397	-0.068
	(0.940)	(0.914)	(0.968)	(0.915)	(0.816)	(0.968)
urban residence	1.793***	1.766***	1.785***	1.824***	1.807***	1.818***
	(0.003)	(0.003)	(0.003)	(0.002)	(0.003)	(0.002)
living alone	-0.922	-0.918	-0.939	-0.887	-0.816	-0.914
	(0.187)	(0.189)	(0.179)	(0.206)	(0.244)	(0.192)
self-reported health	1.714***	1.685***	1.705***	1.772***	1.846***	1.758***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
disease	-0.799**	-0.823**	-0.828**	-0.770*	-0.692*	-0.790**
	(0.044)	(0.039)	(0.037)	(0.053)	(0.081)	(0.047)
income	-0.334	-0.324	-0.340	-0.350	-0.303	-0.349
	(0.319)	(0.334)	(0.310)	(0.296)	(0.365)	(0.297)
pension	1.454***	1.458***	1.448***	1.390***	1.338***	1.405***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.003)	(0.002)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes

Individual FE	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	10920	10920	10920	10920	10920	10920

Note: *** p<0.01, ** p<0.05, *p<0.1; robust standard errors are in parentheses.

4.2 Robustness check

To test the robustness of the baseline results, we choose three alternative variables of age identity. As shown in Table 3, Internet users are much more likely to perceive him/herself not being old than nonusers (Column 1 in Panel A). Internet users tend to feel much younger than their actual age and also look much younger than they actually are (Column 2 and 3 in Panel A). The estimates for the coefficients on use frequency and types of online activities are also generally in line with the baseline regression (Panel B and C).

Table 3. Robustness checks considering different dependent variables.

	(1) age identity2	(2) age identity3	(3) age identity4
Panel A: Being netizen			
netizen	0.075***	0.550*	0.995***
	(0.002)	(0.082)	(0.001)
Panel B: Frequency			
daily user	0.099***	0.622*	1.353***
	(0.000)	(0.068)	(0.000)
non-daily user	0.024	0.406	0.248
	(0.517)	(0.386)	(0.567)
Panel C: Type			
communication	0.081***	0.558*	1.018***
	(0.001)	(0.074)	(0.001)
entertainment	0.065***	0.535*	0.401
	(0.008)	(0.096)	(0.167)
life services	0.009	0.103	0.285
	(0.767)	(0.779)	(0.396)
type score	0.028***	0.0219	0.303**
	(0.008)	(0.113)	(0.019)
Obs.	10920	9720	9634

Note: *** p<0.01, ** p<0.05, *p<0.1; robust standard errors are in parentheses. The control variables, time fixed effects, and individual fixed effects are adjusted in all these models. Since the types of online activities are not mutually exclusive, we perform separate regressions for different types of Internet use.

To address the potential endogeneity discussed above, we apply the fixed-effects instrumental

variables (IV) estimation using two alternative instruments. In the first stage estimation, the rising share of legal entities in information transmission, software, and IT service industry in the province, as a proxy for local development of IT infrastructure, effectively facilitates the use of Internet among older adults (Model 1 of Table 4). The first-stage F-statistics is 77.08, well above the threshold value of 10, ruling out the concern of weak instruments. The second-stage coefficients of internet use stay positive and significant (Model 2), confirming the robustness of fixed effects estimates in Model 1 of Table 2. Similarly, an alternative instrument, the share of older netizens in the prefecture is significantly positively associated with the possibility of using Internet for older respondents (Model 3), and the coefficient for Internet use in the second stage remains robust (Model 4).

Table 4. IV estimates of effects of Internet use on age identity.

	(1)	(2)	(3)	(4)
netizen		5.388*		5.094***
		(0.059)		(0.001)
IV1	0.087***			
	(0.000)			
IV2			0.008***	
			(0.000)	
F-statistic	77.076		240.674	
Obs.	10920	10920	10920	10920

Note: *** p<0.01, ** p<0.05, *p<0.1; robust standard errors are in parentheses; F-statistic refers to Kleibergen-Paap Wald F statistic. The control variables, time fixed effects and individual fixed effects are adjusted in all these models.

4.3 Mediating effect analysis

We then proceed to investigate three potential pathways linking Internet use and age identity of older adults, including social participation, social adaptation, and feeling of worthlessness. Social participation is measured as participation in three types of activities, volunteering, public affairs, and recreational activities. As shown in Table 5, Internet users are significantly more likely to engage in these three types of social activities, and the stimulating effect is the most pronounced for recreational activities. Increased social participation, in turn, is beneficial for holding a positive perception of aging. Model 1 and 2 of Table 6 suggest that the use of Internet could effectively improve the

respondent's social adaption, thereby leading to younger age identity. Model 3 and 4 in Table 6 show that Internet users are much less likely to feel worthless, and thus perceive themselves to become old at a later age.

After adjusting for these five mediators, the coefficients for Internet use are smaller than that in Model 1 of Table 2, but stay significant. This indicates that these five mediators can partially explain the positive link between Internet use and age identity, with the contribution rate being 7.58%, 8.56%, 28.30%, 10.07%, and 4.65% respectively.

Table 5. Estimates of mediating effects of social participation.

	(1) volunteer	(2) age identity1	(3) public affairs	(4) age identity1	(5) recreation	(6) age identity1
netizen	0.091***	1.681***	0.110***	1.664***	0.260***	1.305***
	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.006)
volunteer		1.514***				
		(0.000)				
public affairs				1.416***		
				(0.000)		
recreation						1.981***
						(0.000)
Obs.	10920	10920	10920	10920	10920	10920

Note: *** p<0.01, ** p<0.05, *p<0.1; robust standard errors are in parentheses. The control variables, time fixed effects and individual fixed effects are adjusted in all these models.

Table 6. Estimates of mediating effects of social adaptation and feeling of worthlessness.

	(1) social adaptation	(2) age identity1	(3) feeling of worthlessness	(4) age identity1
netizen	0.259***	1.636***	-0.071***	1.735***
	(0.000)	(0.001)	(0.006)	(0.000)
social adaptation		0.707***		
		(0.000)		
feeling of worthlessness				-1.193***
				(0.000)
Obs.	10920	10920	10920	10920

Note: *** p<0.01, ** p<0.05, *p<0.1; robust standard errors are in parentheses. The control variables, time

fixed effects and individual fixed effects are adjusted in all these models.

4.4 Heterogeneity analysis

The last section is to examine how the impacts of Internet use vary by the socio-demographic characteristics of older adults, including gender, age group, urban-rural residence, and educational attainment. Model 1 and 2 of Table 7 show that both women and men benefit from Internet use, while the positive impact for the female is more prominent. It is possibly because the female has a smaller real-life social network, a wide variety of information and services on the Internet could generate a stronger compensating impact for females by expanding their scope of life and offering more opportunities for social activities (Yang et al., 2022).

As shown in Model 3 and 4, the positive impact of Internet use on age identity is only observed for younger elderly aged 60-74 but not for the oldest-old aged 75+. Similarly, the positive impact of Internet use is significant for urban older adults but not for those living in rural areas (Model 5 and 6). Model 7 and 8 suggest that Internet use promotes a more youthful identity for both the better-educated and the poorly-educated, while the coefficient for the former group is twice as large as that for the latter group. A potential reason for such disparities is that the younger, urban, and better-educated respondents tend to master more mature digital skills and be more capable of identifying risks such as Internet fraud, so that they could better reap the benefits of Internet (Hofer et al., 2019).

Table 7. Heterogeneous effects by gender, age group, residence, and educational attainment

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	By gender		*By age group*		*By urban-rural residence*		*By education*	
	Male	Female	60-74	75+	Urban	Rural	High school and above	Less than high school
netizen	1.696***	1.896***	1.862***	1.513	2.000***	1.067	3.183**	1.635***
	(0.008)	(0.007)	(0.000)	(0.267)	(0.001)	(0.289)	(0.021)	(0.001)
Obs.	5600	5320	7814	2290	6160	4086	1284	9636

Note: *** p<0.01, ** p<0.05, *p<0.1; robust standard errors are in parentheses. The control variables, time fixed effects, and individual fixed effects are adjusted in all these models.

5 Conclusion and Discussion

Digital technology in China has been developing at a breakneck speed and encroaching on every aspect of life in the aging society over the past two decades. Long perceived as technology-averse, older adults are defying stereotypes and embracing the digital age, as shown by the dramatic rise in the Internet penetration rate of this group. Based on the panel data of Chinese older adults aged 60 and above from 2018 and 2020 waves of CLASS, this study comprehensively illustrates how the frequency and purpose of Internet use influence the age identity, an important marker of physical and psychological functioning for older adults.

First, Internet use contributes to a younger age identity as measured by perceived old age, subjective age, or appearance age, echoing the previous findings (Cody et al., 1999; Wang and Gu, 2023; Zhao et al., 2024). Our study further reveals that the benefits of Internet use vary by the frequency and purpose of use. Daily users hold a much younger age identity than non-users, while non-daily use of Internet does not show a significant impact. The use of Internet for communication and entertainment is beneficial for age identity, but no such effect is observed for online life services. Life service apps such as transportation, health management, and banking are often more complicated to handle than the apps for chatting and entertainment, which might hinder the older adults with poor digital skills to fully reap the benefits of Internet.

Second, Internet use enables older adults to increase participation in various offline social activities including volunteering, public affairs, and entertainment, and also to improve their social adaptation, thus perceiving themselves younger than their actual age. Meanwhile, Internet use also motivates older adults to learn new skills and makes them less likely to feel worthless, which leads to a positive perception of aging.

Third, the impact of Internet use on age identity is not uniform but varies by socio-demographic groups. The positive impact is shown to be larger for the female than for the male. As female older adults are more disadvantaged in social capital (Addis and Joxhe, 2017), the relative importance of the Internet for facilitating interpersonal communication and expanding social networks may be greater for females (Yang et al., 2022). Meanwhile, Internet use produces stronger benefits for the younger, urban, and better-educated than the more senior, rural, and poorly-educated counterparts, possibly because the former groups command more advanced digital skills. As suggested by the

resource multiplication theory, the privileged groups gain more from the resources they have, and their advantages are further augmented (Ross and Mirowsky, 2006), exacerbating the existing inequalities.

This study still carries some limitations. First, even though we consider the frequency of Internet use, we do not capture the potentially non-linear effect of time spent online due to a lack of data. With the rising Internet penetration rate among the elderly, Internet addiction for older adults might be an increasingly alarming issue. Therefore, it is worthwhile to investigate whether there is an inverse U-shape relationship between time spent online and age identity for older adults. Second, differential digital skills might be an important factor for the heterogeneous effects of Internet use by sociodemographic groups. As such, if information on digital skills is available, it is necessary to evaluate whether older adults' digital skill serves as a moderator to strengthen the benefits of Internet use for self-perception of age.

Our study has qualified the Internet as a resource for successful aging. China's CPC Central Committee and State Council issued the *Overall Layout Plan for the Construction of Digital China* in 2023, underscoring digitization as a critical engine for China's modernization. In the process of constructing Digital China, it is crucial to bridge the digital divide by designing age-friendly digital products and also to enhance older adults' digital literacy. For instance, tech companies are encouraged to include elderly-friendly settings or modes when designing their products with large fonts, bright colors, and simple functions. Moreover, the government could incentivize urban and rural communities to set up digital hubs staffed with young volunteers to provide one-to-one assistance for older adults. Transformation of the elderly from digital outsiders to digital savants would produce far-reaching benefits for the accelerated aging society of China.

Funding

This work is supported by the National Fund of Social Sciences of China (No. 21&ZD189).

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

1. Alonso Debreczeni, F., Bailey, P.E. 2021. A systematic review and meta-analysis of subjective age and the association with cognition, subjective well-being, and depression. J Gerontol B Psychol Sci Soc Sci. 76(3), 471-482. https://doi.org/10.1093/geronb/gbaa069.
2. Addis, E., Joxhe, M. 2017. Gender gaps in social capital: A theoretical interpretation of evidence from Italy. Feminist Economics, 23, 146-171. https://doi.org/10.1080/13545701.2016.1227463.
3. Baron, R.M., Kenny, D.A. 1986. The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. Journal of Personality and Social Psychology, 51(6), 1173–1182. https://doi.org/10.1037//0022-3514.51.6.1173.
4. Barrett, A.E. 2003. Socioeconomic status and age identity: The role of dimensions of health in the subjective construction of age. J Gerontol B Psychol Sci Soc Sci. 58(2), S101-S109. https://doi.org/10.1093/geronb/58.2.s101.
5. Benvenuti, M., Giovagnoli, S., Mazzoni, E., Cipresso, P., Pedroli, E., Riva, G. 2020. The relevance of online social relationships among the elderly: How using the web could enhance quality of life?. Front Psychol. 11, 551862. https://doi.org/10.3389/fpsyg.2020.551862.
6. Bowling, A., See-Tai, S., Ebrahim, S., Gabriel, Z., Solanki, P. 2005. Attributes of age-identity. Ageing and Society, 25(4), 479–500. https://doi.org/10.1017/S0144686X05003818.
7. Bordone, V., Arpino, B., Rosina, A. 2019. Forever young? An analysis of the factors influencing perceptions of ageing. Ageing and Society. 40, 1669-1693. https://doi.org/10.1017/S0144686X19000084.
8. Carp, F.M., Carp, A. 1981. Mental health characteristics and acceptance-rejection of old age. Am J Orthopsychiatry. 51(2), 230-241. https://doi.org/10.1111/j.1939-0025.1981.tb01369.x.
9. Chen, B. 2008. Social adaptation of the urban elderly in aging era. Journal of Social Science. (6):89-94+191.
10. Chen, X. 2020. Research on the influence and difference of Internet usage on social isolation of the elderly. Contemporary Economic Management. 42(9), 53-59. doi: 10.13253/j.cnki.ddjjgl.2020.09.008.

11. China Internet Network Information Center. 2023. The 52nd Statistical Report on China's Internet Development. https://www.cnnic.net.cn/n4/2023/0828/c88-10829.html.
12. Chopik, W.J. 2016. The benefits of social technology use among older adults are mediated by reduced loneliness. Cyberpsychology, Cyberpsychol Behav Soc Netw. 19(9), 551–556. https://doi.org/10.1089/cyber.2016.0151.
13. Cody, M.J., Dunn, D., Hoppin, S., Wendt, P. 1999. Silver surfers: Training and evaluating Internet use among older adult learners. Communication Education. 48(4), 269–286. https://doi.org/10.1080/03634529909379178.
14. Diehl, M., Wahl, H.W., Barrett, A.E., Brothers, A.F., Miche, M., Montepare, J.M., Westerhof, G.J., Wurm, S. 2014. Awareness of aging: Theoretical considerations on an emerging concept. Dev Rev. 34(2), 93-113. https://doi.org/10.1016/j.dr.2014.01.001.
15. Du, P., Luo Y. 2023. Can Internet use promote the social adaptation level of older adults? An analysis based on the perspective of different usages. Population Research. 47(6), 3-20.
16. Freeman, A.T., Santini, Z.I., Tyrovolas, S., Rummel-Kluge, C., Haro, J.M., Koyanagi, A. 2016. Negative perceptions of ageing predict the onset and persistence of depression and anxiety: Findings from a prospective analysis of the Irish Longitudinal Study on Ageing (TILDA). J Affect Disord. 199, 132-138. https://doi.org/10.1016/j.jad.2016.03.042.
17. Hage, E., Wortmann, H., van Offenbeek, M. and Boonstra, A. 2016, The dual impact of online communication on older adults' social connectivity, Information Technology & People. 29(1), 31-50. https://doi.org/10.1108/ITP-09-2014-0216.
18. He H., Yan C. 2022. Segregation or integration: A study of the impact of Internet use on community participation of Chinese elderly. Population Journal. 44(2), 72-84. doi: 10.16405/j.cnki.1004-129X.2022.02.006.
19. Heo, J., Chun, S., Lee, S., Lee, K.H., Kim, J. 2015. Internet use and well-being in older adults. Cyberpsychology, behavior and social networking, 18 5, 268-72. http://;.org/10.1089/cyber.2014.0549 .
20. Ihm, J., Hsieh, Y.P. 2015. The implications of information and communication technology use for the social well-being of older adults. Information, Communication & Society, 18(10), 1123–1138. https://doi.org/10.1080/1369118X.2015.1019912.
21. Hofer M., Hargittai E., Büchi M., Seifert, A. 2019. Older adults' online information seeking and

subjective well-being: The moderating role of internet skills. International Journal of Communication, 13, 4426-4443.

22. Jose, J.P., Cherayi, S. 2017. Age identity and psychosocial disability in older persons of Kerala. Indian Journal of Geron- tology, 31(1), 20-42.
23. Judd, C.M., Kenny, D.A. 1981. Process analysis: Estimating mediation in treatment evaluations. Evaluation Review, 5(5), 602–619. https://doi.org/10.1177/0193841X8100500502.
24. Kastenbaum, R., Derbin, V., Sabatini, P., Artt, S. 1972. "The Ages of Me": Toward personal and interpersonal definitions of functional aging. Aging and Human Development. 3(2), 197-211. https://doi.org/10.2190/TUJR-WTXK-866Q-8QU7.
25. Kaufman, G., Elder-Jr, G.H. 2002. Revisiting age identity: A research note. Journal of Aging Studies. 16(2), 169–176. https://doi.org/10.1016/S0890-4065(02)00042-7.
26. Kavirajan, H., Vahia, I.V., Thompson, W.K., Depp, C., Allison, M., Jeste, D.V. 2011. Attitude toward own aging and mental health in post-menopausal women. Asian J Psychiatr. 4(1),26-30. https://doi.org/10.1016/j.ajp.2011.01.006.
27. Keyes, C.L., Westerhof, G.J. 2012. Chronological and subjective age differences in flourishing mental health and major depressive episode. Aging Ment Health. 16(1), 67-74. https://doi.org/10.1080/13607863.2011.596811.
28. Kleinspehn-Ammerlahn, A., Kotter-Grühn, D., Smith, J. 2008. Self-perceptions of aging: do subjective age and satisfaction with aging change during old age?. J Gerontol B Psychol Sci Soc Sci. 63(6), 377-385. https://doi.org/10.1093/geronb/63.6.p377.
29. Kotter-Grühn, D., Hess, T.M. 2012. So you think you look young? Matching older adults' subjective ages with age estimations provided by younger, middle-aged, and older adults. International Journal of Behavioral Development, 36, 468-475. https://doi.org/10.1177/0165025412454029.
30. Kraut, R., Patterson, M., Lundmark, V., Kiesler, S., Mukopadhyay, T., Scherlis, W. 1998. Internet paradox. A social technology that reduces social involvement and psychological well-being? Am Psychol. 53(9), 1017-1031. https://doi.org/10.1037//0003-066x.53.9.1017.
31. Lam, S.S.M., Jivraj, S., Scholes, S. (2020). Exploring the relationship between Internet use and mental health among older adults in England: Longitudinal observational study. J Med Internet Res., 22(7), e15683. https://doi.org/10.2196/15683.

32. Levy, B.R., Slade, M.D., Kunkel, S.R., Kasl, S.V. 2002. Longevity increased by positive self-perceptions of aging. J Pers Soc Psychol. 83(2), 261–270. https://doi.org/10.1037//0022-3514.83.2.261.
33. Maalaoui, A., Partouche, J., Safraou, I., Viala C. 2023. Senior entrepreneurship: How subjective age affects seniors' entrepreneurial intentions. Rev Manag Sci 17, 443–465. https://doi.org/10.1007/s11846-022-00537-5.
34. Meshi, D., Ellithorpe, M.E. 2021. Problematic social media use and social support received in real-life versus on social media: Associations with depression, anxiety and social isolation. Addict Behav. 119, 106949. https://doi.org/10.1016/j.addbeh.2021.106949.
35. Ni, C., Wang, Z. 2022. The impact of Internet use on social isolation in older adults. Population Journal. 44(3), 59-72. doi: 10.16405/j.cnki.1004-129X.2022.03.005.
36. Nie, P., Sousa-Poza, A., Nimrod, G. 2017. Internet use and subjective well-being in China. Soc Indic Res. 132, 489–516. https://doi.org/10.1007/s11205-015-1227-8.
37. Ranchordás, S. 2020. Connected but still excluded? Digital exclusion beyond Internet access. SSRN Electronic Journal. http://dx.doi.org/10.2139/ssrn.3675360.
38. Ross, C.E., and Mirowsky, J. (2006). Sex differences in the effect of education on depression: Resource multiplication or resource substitution? Social Science & Medicine, 63(5), 1400–1413. https://doi.org/10.1016/j.socscimed.2006.03.013.
39. Schulz, R., Wahl, H.W., Matthews, J.T., De Vito Dabbs, A., Beach, S.R., Czaja, S.J. 2015. Advancing the aging and technology agenda in gerontology. The Gerontologist 55:724–734. https://doi.org/10.1093/geront/gnu071.
40. Seifert, A., Wahl, H.W. 2018. Young at heart and online? Subjective age and internet use in two Swiss survey studies. Educational Gerontology, 44(2-3), 139–147. https://doi.org/10.1080/03601277.2018.1427495.
41. Shanahan, M.J., Elder, G.H., Jr. 2002. History, agency, and the life course. In L. J. Crockett (Ed.), Agency, motivation, and the life course (pp. 145–186). University of Nebraska Press.
42. Shi S, Zhang L, Wang G. 2023. Bridging the digital divide: Internet use of older people from the perspective of peer effects. Sustainability. 2023, 15(15), 12024. https://doi.org/10.3390/su151512024.
43. Sims, T., Reed, A.E., Carr, D.C. 2017. Information and communication technology use is related

to higher well-being among the oldest-old. The journals of gerontology. Series B, Psychological sciences and social sciences, 72(5), 761–770. https://doi.org/10.1093/geronb/gbw130.

44. Slegers, K., van Boxtel, M.P., Jolles, J. 2008. Effects of computer training and Internet usage on the well-being and quality of life of older adults: a randomized, controlled study. J Gerontol B Psychol Sci Soc Sci. 63(3), 176-184. https://doi.org/10.1093/geronb/63.3.p176.
45. Sum, S., Mathews, R. M., Hughes, I., Campbell, A. 2008. Internet use and loneliness in older adults. Cyberpsychol Behav.: the impact of the Internet, multimedia and virtual reality on behavior and society, 11(2), 208–211. https://doi.org/10.1089/cpb.2007.0010.
46. Sun, K., Zhou, J. 2021. Understanding the impacts of Internet use on senior citizens' social participation in China: Evidence from longitudinal panel data. Telematics Informatics, 59, 101566. https://doi.org/10.1016/j.tele.2021.101566.
47. United Nations. 2022. World Population Prospects 2022, Online Edition. https://population.un.org/wpp/.
48. Wang, K., Gu, D. 2023. Does Internet use promote older adults' self-perception of aging: separating within- and between-person effects. Innovation in Aging. 7, 837, https://doi.org/10.1093/geroni/igad104.2700.
49. Yang, M., Li, Z., Li, L. 2022. Internet access and mental health among Chinese older adults——Based on two levels of digital inequality. Population and Development. 28(6), 132-147.
50. Yu, D., Fiebig, D.G. 2020. Internet use and cognition among middle-aged and older adults in China: A cross-lagged panel analysis. The journal of the economics of ageing. 17, 100262. https://doi.org/10.1016/j.jeoa.2020.100262.
51. Yu, X., Wang, Q. 2023. Old Age Identity and Employment Choice of the Elderly in China. Economic Perspectives. 9, 92-110.
52. Zhao, M., Huang, Y., Zhang, Y. 2024. Could 70 be the new 60? Investigating the association between internet use and subjective age among Chinese older adults. J Gerontol B Psychol Sci Soc Sci. 79(4), gbad200. https://doi.org/10.1093/geronb/gbad200.
53. Zhou, H., Zhang, X., Ge, C., Wang, J., Sun, X. 2023. Does Internet use boost the sustainable subjective well-being of rural residents? Evidence from rural China. Sustainability. 15(2), 1652. https://doi.org/10.3390/su15021652. ß