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Internet exposure during adolescence and age at first marriage

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ABSTRACT

The expansion of the internet has provided people with more channels to obtain information. New information about the world and other lifestyles provided by the internet may affect teenagers' attitudes and change their behavior of first marriage in adulthood. Using data from China Family Panel Studies, this paper explores a national policy reform of the internet in 2000 and combines a difference-in-difference framework with a discrete-time hazard model to estimate the impact of internet exposure in adolescence on women's age at first marriage. The results show that internet exposure during adolescence significantly reduces the risk of women's age at first marriage. No change is observed in men of similar age. Further analysis of the mechanism shows that women's education or search costs in the marriage market cannot explain the findings. In contrast, women's traditional attitudes toward gender roles vary with internet exposure. Their gender role attitudes become more egalitarian, and their attitudes toward marriage become more open. Exposure to the internet also makes women even more reluctant to enter marriage, an institution that is increasingly differentiated by traditional gender roles.

1. Introduction

High-speed internet is considered an important part of economic development and social change. Since the beginning of the 21st century, the internet has played an indispensable role in people's lives. According to the 47th "Statistical Report on the Development of China's Internet Network" released by the China internet Network Information Center (CNNIC), as of December 2020, the number of China's internet users has increased from 8.9 million in 1999 to 989 million in 2020. The internet penetration rate has reached 70.4 %. Meanwhile, China is experiencing a declining marriage rate and a rising marriage age. Although demographic changes have been cited as one of the main reasons for the phenomenon, they are also a result of social and economic changes, including women's attitudes toward marriage and fertility.

The expansion of internet applications appears at three levels according to prior research: the mutual integration of technology itself; the use of emerging technologies for microeconomic activities; and the gradual role of new technologies on human behavior, culture, thought and ideology. Compared with the first two levels of research, the literature on the role of technology in culture and ideology is rare. With the development and popularization of internet technology in various countries, people have more channels to obtain information and access more diversified values. The explosive growth of information is likely to have a certain impact on the psychological and emotional shaping of adolescents (McDool et al., 2020). Adolescents are exposed to multiple tasks, such as value

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shaping and emotional development, and these early-formed ideas are likely to have a lasting impact on behavioral decision-making in adulthood (Sutter et al., 2019).

Considering the above phenomenon and the research gap in the literature, this paper empirically examines the impact of internet exposure in adolescence (12–18 years old) on the decision of first marriage by using data from the 2016 to 2018 waves of the China Family Panel Studies (CFPS). We explore China's internet expansion policy beginning in 2000 as a quasi-experiment for model identification. Considering the issue of data censoring (some individuals were keeping unmarried when they attended the survey), we combine a difference-in-difference framework with survival analysis to estimate the causal effect. As a preview of the results, the experience of the rapid development of the internet in adolescence significantly reduces the risk of women's first marriage by delaying their marriage age. Moreover, the experience of exogenous internet expansion in early adolescence is more likely to increase the duration of being single than in later stages of adolescence for women. In contrast, no similar effect is observed on a sample of men or on individuals in rural areas.

In the following analysis of the potential underlying mechanism, we first rule out the impact of internet experience on an individual's educational attainment. Prior studies suggest that an increase in education postpones the age of first marriage for women (Tian, 2013; Yu & Xie, 2015). However, we find no evidence that adolescent internet exposure changes their final educational attainment in the analysis sample. In other words, education is unlikely to be a working mechanism that drives the benchmark results in the current paper. We further rule out the reduction in the search cost in the marriage market generated by internet expansion, which in turn leads to changes in the risk of first marriage (Bellou, 2015; Rosenfeld & Thomas, 2012). Finally, we show supportive evidence that internet exposure in adolescence can significantly affect women's perceptions of marriage over the long term, which in turn leads to the delay of marriage. We propose that gender attitude could be an important and novel channel that has been altered by the internet and overlooked in the literature.

The current study contributes to the literature in three possible ways. First, despite the large number of studies on internet-related issues, most focus on the theory of searching cost and information asymmetry and examine how internet technology addresses the constraint and alters economic and social development, including the labor market (Akerman et al., 2015; Atasoy, 2013; Chen et al., 2020; Kroft & Pope, 2014). Recent studies shift more attention to the formation and dissolution of individual marriage (e.g., Bellou, 2015; Kendall, 2011; Rosenfeld & Thomas, 2012) and fertility (Billari et al., 2019).[1] However, there is a lack of research on the internet experience in adolescence and behavioral decision-making in adulthood. In a related study, McDool et al. (2020) show that the time teens spend online squeezes out the time they spend on other benignant activities, which in turn negatively affects their mental health. On this basis, our paper further analyzes the impact of adolescents' internet experience on their long-term behavioral decisions, i.e., their age at first marriage.

Second, this paper extends the existing literature on the age at first marriage for women. Prior literature mainly explains the declining marriage rate and rising marriage age from three aspects: the increase in female labor force participation, the decline in the fertility rate, and the increase in educational attainment (Becker, 1973; Oppenheimer, 1988, 1994). The age at first marriage in China has been rising in the past two decades, from 22.79 years old in 1990 to 24.85 years old in 2010 on average. The increase is more obvious among women than men, especially women in urban areas.[2] Changes in patterns of first-time marriage can undoubtedly have a huge impact on the demographic and economic structure of a country. When analyzing the reasons for the postponement of women's marriages, scholars mainly focus on the substantial improvement of women's education and their economic independence (Tian, 2013), real estate prices (Wrenn et al., 2019), and premarital cohabitation. Few studies pay attention to the changes in first-marriage behavior caused by the development of internet technology. We add to the literature by examining the role of technology in shaping an individual's attitude and ideology.

Finally, in terms of model specification and identification, we make an improvement on the traditional linear different-in-difference model by employing a combination of the DD framework and discrete time hazard model. The proposed method has two advantages for conducting the empirical estimates of the question being analyzed. On the one hand, it can effectively solve the data censoring problem of age at first marriage. On the other hand, it incorporates a set of time-varying and time-invariant variables at the individual and regional levels to each spell and addresses the potential influence of confounding factors as much as possible. We argue that the application of the DD framework and duration model makes the long-term effect estimated in this paper more convincing.

The remainder of the paper is organized as follows. In Section 2, we introduce the background for the development of the fast internet in China. In Section 3, we discuss the identification strategy and the hazard model as well as the dataset used in the analysis. Section 4 presents the estimation results and sensitivity checks. Section 5 outlines several potential mechanisms. Section 6 presents our conclusions.

[1] According to a study by Rosenfeld and Thomas (2012), internet technology is the second most popular place to meet a partner after traditional offline social networks, especially among young people. Bellou (2015) found that the expansion of the internet is significantly associated with increased local marriage rates. At the same time, the research shows that the internet has sidelined other traditional ways of meeting potential partners, and that online dating services have helped increase marriage rates.

[2] For details, please refer to a review by Yu and Xie (2015) on the determinants of Chinese urban women's first marriage in the past 60 years.

2. Background

2.1. The development of the fast internet in China

The internet has helped China step into a super connected society represented by 5G and artificial intelligence from a weakly connected society in the past. Broadband construction is the backbone of information infrastructure. Reviewing China's broadband construction, the establishment of the "Zhongguancun National Computing and Networking Facility of China" project (hereinafter referred to as NCFC) in 1989 marks the official opening of the process of China's internet construction. In April 1994, the NCFC network realized a full-function connection with the internet, and China became a member of the international community that truly has a full-function internet. With the increasing number of people using the internet, China's four backbone networks, CSTNet, Chinanet, CERNET and UniNet, have also been gradually established. In addition, the China Internet Network Information Center (CNNIC) released the first statistical report on the development of China's internet. The report shows that as of October 31, 1997, China had 620,000 internet users, 4066 domain names registered under CN and approximately 1500 WWW sites.[3]

The growth of the scale of internet use also puts forward the demand for the timeliness and capacity of information transmission. For example, when users of two different internet operators communicate, data can be exchanged directly if there is an interconnection agreement signed between operators. However, multiple transfers are required through the operator with the interconnection agreement if there is no interconnection agreement. Therefore, the transmission speed is much slower, and the probability of data loss increases significantly for interconnections between different backbone networks. A common option for such facilities to support interconnections is the public internet switching center. As a physical node between different networks, the internet switching center can shorten the ISP path of transmission and reduce the delay. The Chinese government noted the importance of interconnection and proposed establishing an internet switching center in 1997.

In 2000, the Chinese government launched a project to improve the speed of network access. At the end of March of the same year, to improve the network speed, China's first national internet switching center was put into operation in Beijing and completed access with nine backbone network operators, including China Telecom, China Mobile, China Unicom, education network, science and technology network, and Great Wall network. The establishment of the switching center is conducive to reducing the cross-regional rotation of traffic, realizing the local exchange of traffic, and greatly improving the network bandwidth of China's main backbone networks. The scheme has two characteristics. First, the time delay and network redundancy are reduced, and the efficiency of network information exchange is significantly improved because the scale of information packet forwarding is shortened. For example, the average access speed between China's backbone networks jumped from 8 mbps to 155 mbps because of the upgrading of interconnection channels. Second, users of each backbone network can access other websites outside the network after the launch of "Beijing IX." Therefore, they can receive multiplied information and expand the type of interactive information. In short, users obtain and exchange information more broadly and faster after upgrading.

The smoothness of the network has an important impact on the development of the website and user scale. At the end of 2000, China had 22.5 million internet users, 122,099 domain names registered under CN and approximately 265,405 WWW sites. At the end of 1999, CNNIC reported that the number of internet users was only 8.9 million. There were approximately 48,695 domain names registered under the CN and 15,153 WWW sites. The activity of China's internet has achieved explosive growth. CNNIC's survey report on internet users at the end of 1999 showed that slow-speed internet and limited searched information ranked the top three most unsatisfactory complaints among users, with proportions of 52.98 % and 7.35 %, respectively. In particular, slow speed was the primary concern of users, while at the end of 2000, the proportion of the two reasons fell to 46.41 % and 6.41 %, respectively.

Since then, China has opened gigabit broadband lines and upgraded bandwidth many times. In July 2012, the "Broadband China" project was proposed in the 12th Five Year Plan for the development of national strategic emerging industries issued by the State Council. The project aimed to promote the development of China's broadband in three stages and realize broadband access capacities of 20 mbps and 4 mbps in urban and rural areas by 2015. In 2015, the Ministry of Commerce and 10 other departments jointly issued the national distribution node city layout plan (2015–2020), which determined the three vertical and five horizontal national backbone distribution channel systems in 2015–2020, further promoting the construction of broadband infrastructure in China.

To wrap up the prior description of China's development of fast internet infrastructure, the current paper exploits the internet acceleration policy in 2000 as a quasi-experiment and evaluates the policy shock on adolescents' internet exposure and their marriage decision in adulthood.

2.2. Research hypothesis

Adolescence is the key period in formation of values and marriage concept. It is also a stage of early and heavy exposure to the internet and media. During individual's adolescence, internet and media in general are effective in curbing their thought because of two schemes: information role and education role.

First, fast internet provides a more efficient way of information distribution. In theory, the transmission and diffusion efficiency of all kinds of information in society plays an important role in the dissemination of existing technologies and the emergence of new technologies. On the one hand, as the network transmission speed is accelerated, the information interaction speed is also promoted.

[3] China Internet Network Information Center (CNNIC). The first statistical report on the development of internet in China Netcom, May 2, 2014, Available at http://www.cac.gov.cn/2014-05/26/c_126547412.htm (accessed on February 14, 2022).

On the other hand, faster and less expensive networks reduce the cost of information access and revolutionize the mode of social value creation and economic development (Akerman et al., 2015; Atasoy, 2013; Chen et al., 2020; Kroft & Pope, 2014). The internet addresses the information asymmetry and decision biases by inducing people to update their beliefs. This channel is particularly important for developing countries (La Ferrara, 2016). Moderate exposure to internet may lead to substantial updates in beliefs and changes in social behavior.

Second, internet helps people see and learn from role models and hence plays an effective educational role. Gender identity is formed through the process of internalizing social norms (Liu & Zuo, 2019).[4] This process begins with family life. Communities, schools, and peers reinforce the existing gender role expectations. Internet provides a learning environment where individuals adopt behaviors and value of a group. Reference group effects resulting from exposure to role models and lifestyles transform via media. Traditionally, parents, peers, school, and neighborhoods have major responsibility for shaping the learning environment. Over the past decades, numerous studies reveal that mass media play a very important role in the gender-role socialization process for child and adolescents. For instance, the online movements with themes related with criticism of traditional values and the circulations of modern ideas such as female empowerment in both work sphere and private life are having a growing impact on young people. Some direct research also proves that the internet can effectively change gender identity through education channels and make the social role orientation of gender tend to be egalitarian. The effect is particularly stronger for women and rural residents (Zhou et al., 2020).

Kearney and Levine (2015) find that TV programs that describe the living conditions of teenage mothers significantly reduce the risk of pregnancy among adolescents between 15 and 19 years old. Gerber et al. (2009) find that newspaper exposure affects voting behavior and attendance behavior. Jensen and Oster (2009) show that the introduction of cable television improves the status of rural women in India. La Ferrara et al. (2012) find that women's exposure to soap operas has a significant negative impact on fertility in Brazil. Based on the above theoretical frame and empirical evidence, we propose that the acceleration of the internet may change the marriage view of teenagers, especially under China's traditional value concept of "the Domestic Wife and Social Husband". The impact of the external world brought by internet information may change women more obviously and then affect their first marriage decision-making.

3. Method and data

3.1. Model specification and identification strategy

Based on China's internet acceleration policy beginning in 2000 as a natural experiment, this paper uses a difference-in-difference framework to identify the impact of internet experience in adolescence on women's first marriage in adulthood. As mentioned above, although the internet switching center can improve China's overall broadband access speed, the effect may be heterogeneous. The main factor determining the implementation effect is the existing internet infrastructure construction level of the cities involved in the policy, which we can call "the last mile technology." At the beginning of the backbone interconnection project, all cities were equipped with a certain amount of internet infrastructure. Therefore, prefecture-level cities with a high level of internet infrastructure tend to benefit more from the speed and capacity upgrading of the backbone network, which is also the variation for identification in the paper. The main model specification is as follows.

$$\begin{aligned} firstmarriage_{i,c,p} &= \alpha + \beta_1 Infrastructure_{c,1999} \times partly_{i,p} \\ &+ \beta_2 Infrastructure_{c,1999} \times fully_{i,p} + X'_{i,c,p}\gamma \\ &+ \eta_c + \kappa_p + W'_{c,1999} \times \kappa_p + \varepsilon_{i,c,p} \end{aligned} \tag{1}$$

Where i, c, and p refer to individual, city, and year, respectively. $firstmarriage_{i,c,p}$ indicates the age of first marriage of an individual, and $Infrastructure_{c,1999}$ indicates the (natural log) proportion of fixed line telephone users in the total population of the city in 1999. The proportion of fixed line users in the region can be used as a proxy variable for broadband internet access (Chen et al., 2020). On the one hand, the internet is first introduced to Chinese household in the late 1990s in the form of dial-up internet, which deploys the fixed line telephone infrastructure. The regions with higher proportions of fixed-line telephone users at that time are therefore more likely to get earlier access to dial-up internet, as well as the later developments in network communications including the broadband network. On the other hand, the pre-existing heterogeneity in infrastructure itself determines the differential reach of the broadband network, since the fixed line infrastructure elements are often the preconditions for broadband deployment (Czernich et al., 2009). In other words, the higher the proportion of fixed line users in the region, the greater the possibility of dial-up internet access. Therefore, the treatment variable $Infrastructure_{c,1999}$ is continuous rather than binary. $partly_{i,p}$ is a dummy variable that takes a value of 1 for individuals with birthyears between 1982 and 1988 and 0 otherwise. $fully_{i,p}$ is also binary and takes 1 for individuals with birthyears between 1988 and 1990 and 0 otherwise. The coefficients of the interaction items $Infrastructure_{c,1999} \times partly_{i,p}$ and $Infrastructure_{c,1999} \times fully_{i,p}$ are the focus of the current paper, which represent the impact of individuals who have partially experienced internet reform and fully experienced internet reform at the age of 12–18 on their first marriage decision-making in the future, respectively. We expect a larger and more significant coefficient of $Infrastructure_{c,1999} \times fully_{i,p}$ than $Infrastructure_{c,1999} \times partly_{i,p}$ if a longer adolescent experience of the

[4] The role that a woman is expected to play in marriage, family, work, and other situations is called gender identity, which is a kind of social and cultural identity described in the literature.

internet indeed has a larger impact on future marriage decision-making. In the robustness check, we further decomposed the age group and scrutinized the potential different impacts of exposure intensity among multiple age groups in the adolescence period.

$X'_{i,c,p}$ is a set of control variables, including time-varying and time-invariant characteristics at the individual and city levels, and η_c is the city fixed effect and absorbs time-invariant heterogeneity across cities. Similarly, κ_p is the year of birth fixed effect and absorbs time-invariant heterogeneity across different birth cohorts. To solve the potential heteroscedasticity and sequence autocorrelation problems, we cluster the standard error at the city level.

A potential problem of the identification strategy is that the intensity of internet influence in various regions may not be random. For example, the regions with a high proportion of fixed line users may also be more developed, which also affects the first marriage decision of individuals in the region of residence. To alleviate the concern of identification, we use a similar practice as Chen et al. (2020) and add a group of interactions of city pretreatment characteristics $W'_{c,1999}$ (population size and GDP of prefecture-level cities in the base year of 1999) and individual birth year dummies κ_p.

However, the linear estimates of Eq. (1) with OLS may face the problem of data censoring and result in selection bias. For example, for individuals born in 1990, we can only observe their marriage history up to the age of 28 in CFPS 2016. Therefore, the problem of missing data cannot be solved by using OLS estimates. Instead, this paper uses a survival analysis model. Compared with OLS estimates, survival analysis can not only solve the problem of data censoring but also alleviate the key assumption of parallel trends in a DD framework. The parallel trend assumption requires that the treatment group and the control group follow the same pattern over time without the internet expansion policy. However, this is a strong assumption in the real world. For example, other demographic and marriage-related policies may have taken place in the same period of being analyzed, which may also affect first marriage decisions, making it difficult for us to separate these unobservable policy shocks from the benchmark results. Here, we can effectively alleviate the hypothesis of a parallel trend in a DD framework by adding a set of time-varying individual characteristics and regional macro characteristic variables.

To precisely estimate the impact of adolescent experience on the duration of marital status (being single), we construct the following proportional hazard model (PHM).

$$\begin{aligned}\theta(t|x_i(\tau+t)) &\equiv \lim_{h\to 0}\frac{prob[t+h>T_i>t|x_i(\tau+t)]}{h} \equiv \lambda_0(t)exp(\beta x_i(\tau+t))\\ &= \lambda_0(t)exp\big(\alpha+\beta_1 Infrastructure_{c,1999}\times partly_{i,p}\\ &\quad +\beta_2 Infrastructure_{c,1999}\times fully_{i,p}+X'_{i,c,p}\gamma\\ &\quad +\eta_c+\kappa_p+W'_{c,1999}\times\kappa_p\big)\end{aligned} \tag{2}$$

Where T_i represents the duration variable of individual i's marital status (being single) at the beginning of time τ. $\lambda_0(t)$represents the unknown baseline hazard function. $x$represents observable (individual and city level) time-varying and time-invariance variables, which is completely consistent with Eq. (1). Among them, $\beta_1$and$\beta_2$indicate the impact of partial exposure to internet upgrading and full exposure to internet upgrading on the duration of being unmarried or the risk of first marriage, respectively. The change in the hazard rate based on the coefficient is given by $e^{\beta}-1$.

Among them, T_i can be divided into interval data with an equal time length (e.g., 1 year). For example, the$k$ interval can be expressed as $[(k-1)L,kL]$, $k=Int[t/L]+1$. Assume that the value of the explanatory variable$x_i(\tau+t)$does not change with time in each interval. Given the (single) duration t, the probability that an individual chooses not to marry within the time range $t+L$ can be expressed as follows.

$$\begin{aligned}prob[T_i>t+L|T_i>t,x_i(\tau+t)] &= \exp\left[-\int_t^{t+L}\theta(\mu|x_i(\tau+\mu))d\mu\right]\\ &= exp\left[-exp(\beta x_i(\tau+t))\int_t^{t+L}\lambda_0(\mu)d\mu\right]\\ &= exp\big[-exp\big(\beta x_{i,\tau}(k)+\delta(k)\big)\big]\end{aligned} \tag{3}$$

Where,

$$x_{i,\tau}(k)\equiv x_i\big(\tau+t\big)$$

$$\delta(k)\equiv \ln\int_{(k-1)L}^{kL}\lambda_0(\mu)d\mu = \ln\int_t^{t+L}\lambda_0(\mu)d\mu$$

Based on the above model specification, we can construct a likelihood function to estimate the duration of a single status of individuals in the sample (in discrete time).

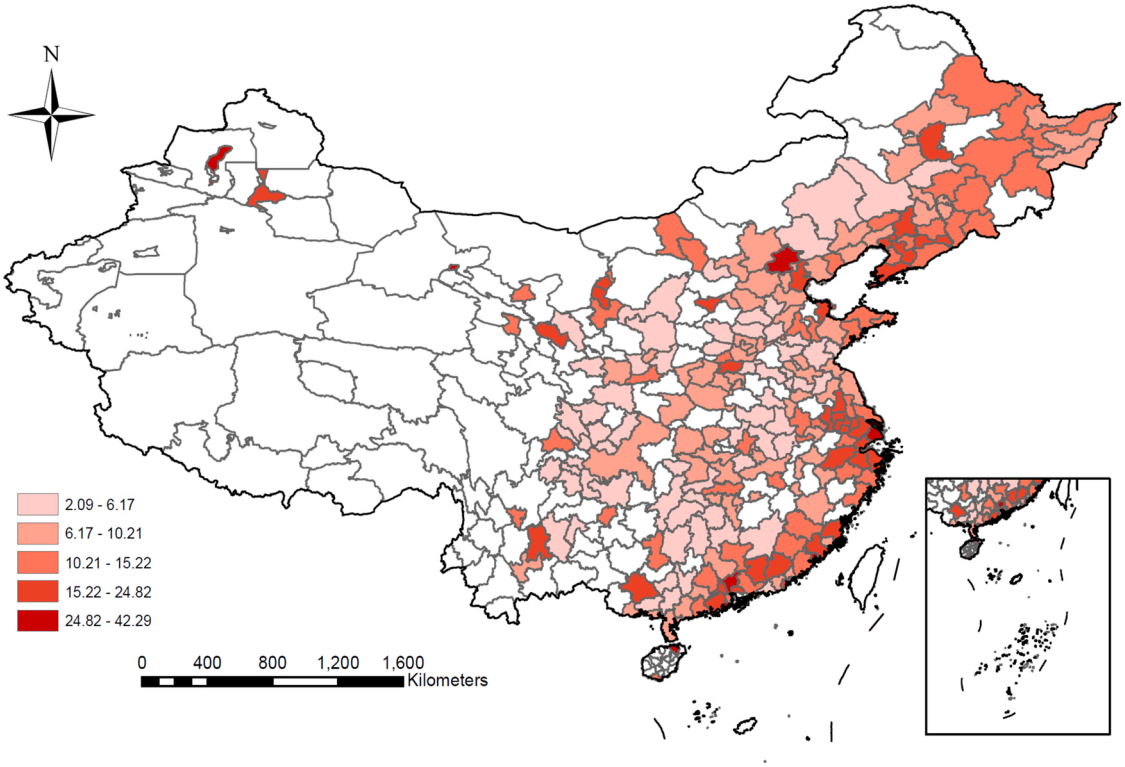

Fig. 1. Distribution of the fixed line of municipalities in 1999.

$$L\left(\alpha,\beta,\delta\right)=\prod_{i=1}^{N}\left(1-\exp\left[-\exp\left(\beta x_{x,j}\left(K_{i,j}\right)\right)+\delta\left(K_{i,j}\right)\right]\right)^{D_{ij}}\prod_{k=1}^{K_{ij}-1}\left(\exp\left[-\exp\left(\beta x_{i,\tau}(k)\right)+\delta(k)\right]\right) \tag{4}$$

We assume that C_i represents the time of individual right censoring, $D_i = 1$ if $T_i \leq C_i$, and$D_i = 0$ otherwise. K_i is the length of interval data (in 1 year unit), $K_i = \min[T_i, C_i]/L + 1.\delta = [\delta(1), \delta(2)\ldots\delta(K)]$ represents the piecewise parameter in the baseline hazard function.[5] We assume that the decision-making of marriage starts at the age of 19. According to the sample size of each interval, we estimate 10 piecewise parameters.[6]

3.2. Data and sample

The individual-level data in the empirical analysis come from the 2016 to 2018 China Family Panel Studies, combined with statistical yearbook data at the regional levels. The CFPS is a longitudinal survey initiated by the China Social Science Survey Center of Peking University. It aims to collect information at the individual, family and community levels and track and record the dynamic changes in many fields of Chinese society in an all-around way. The survey covers many topics, including family relations, population mobility, education, marriage history and social communication. We identify it as the best available dataset for the research question in the current paper to the best of our knowledge.

We make the following steps for sample selection. First, we delete observations who were born before 1980 by considering the implementation time of China's one-child policy and ensuring that individuals in the sample period are comparable. Therefore, the sample of analysis consisted of individuals who were born between 1980 and 1990 in the CFPS 2016 adult survey. To observe a more complete history of personal marriage, we incorporate the CFPS 2018 survey into the sample. Specifically, we obtain the time of first marriage for individuals who reported being married in the 2016 survey. For those unmarried individuals in 2016, we tracked their marital status in the 2018 survey. Second, the current location of the respondents may not be consistent with the location of their adolescence period because of migration and other reasons. Therefore, we retain individuals whose birthplace is completely the same

[5] It thus requires no assumption on the functional form of the baseline hazard function and is more flexible than parametric specifications.

[6] In our sample period, there are relatively few unmarried individuals over the age of 30, so we set each year before the age of 30 as an unknown parameter, and set the same unknown parameter for individuals who aged 30 or above.

Table 1
Summary statistics.

Variable	Female	Male
Time-varying variables		
Studying in school	0.16	0.07
Annual wage in a city	27.39	36.29
Per capita GDP in a city	28.49	36.30
Housing price in a city	3.70	4.71
Sex ratio in a province	105.16	105.01
Time invariant variables		
Internet infrastructure (log)	2.45	2.45
Urban resident	0.62	0.56
Han	0.96	0.94
Education attainment	11.22	10.75
Paternal education	7.41	7.05
Maternal education	5.64	4.84
N	5577	6285

Notes: Individual-level data are from CFPS and restricted to individuals born between 1980 and 1990. The annual average wage, per capita GDP, internet infrastructure (proportion of fixed line users), sex ratio, and housing price are from the China Regional Statistical Yearbook 1999–2017.

as the current location of residence. This helps avoid measurement error and ensure that the impact of internet experience in adolescence on future marriage decisions can be accurately identified. Third, the legal age of marriage in China is 22 for men and 20 for women according to the marriage law of 1980. However, in CFPS data, some individuals have married prior to the minimum legal age. We set the individual marriage decision to start at the age of 19. Since it is very rare for individuals over the age of 38 to get married, we treat individuals above 38 years old as being unmarried.

The individual level variables used in this paper include locality (urban versus rural residence), Han nationality, studying in school, years of education, and parental years of schooling. Among them, whether an individual is studying at school at the time of the survey is a time-varying variable. School attendance generally hinders the formation of first marriage. Therefore, this paper defines an individual's school attendance at all ages according to the highest degree completed (Tian, 2013). For example, if a woman's highest degree is a bachelor's, we define that she is a student in school before the age of 22 and a nonstudent after the age of 23.

The key variable of interest, internet infrastructure, is from the China regional statistical yearbook. Fig. 1 shows the proportion of fixed line telephone users among the population of all prefecture-level cities in 1999.[7] Compared with the western region, the proportion of fixed line users in the central and eastern regions is generally higher, which may also reflect the differences in regional economic conditions. As described in the empirical model specification, we add the interaction term of regional economic indicators in 1999 and an individual's birth year to the control variable set and alleviate the possible nonrandomness of internet upgrading. To eliminate the measurement error, we also use the mean value of the fixed line proportion from 1997 to 1999 to replace the fixed line proportion in a single year in the robustness check.

To further exclude the impact of regional heterogeneity (rather than the internet experience itself) on an individual's marriage decision-making, we add a set of time-varying variables at both the municipal and provincial levels. Time-varying variables at the city level include the annual average wage, per capita GDP, and real estate price. Local economic development and real estate prices are generally considered to affect an individual's marriage decisions (Wrenn et al., 2019). In addition, we add the annual gender ratio of men and women in various provinces because municipal-level measures are unavailable. Individuals who were born between 1980 and the 1990s in this sample may experience an unbalanced sex ratio because of the implementation of the one-child policy, which affects marriage decision-making as well (Angrist, 2002; Du et al., 2021).

Table 1 presents the descriptive statistics of the variables in the regression analysis. The proportion of unmarried respondents being defined during our sample period is 21.5 %. Combining the information on marital history, we obtain a total of 11,862 observations. Each observation presents a person-year point of life from 19 years old to the age of first marriage. For example, a woman who marriage at age 25 has several observations representing seven person-year exposure to the risk of marriage during 19–25 years old. After transforming the duration of marital status into individual-level panel data, we obtain 5577 observations for females and 6285 observations for males. The sample comes from 95 prefecture-level cities in China, of which 58.8 % are urban and 41.2 % are rural residents.

[7] It is important to note that due to the differences in economic development between rural and urban areas, when calculating the proportion of fixed-line telephones in prefecture-level cities, we assign corresponding values according to the urban and rural areas where individuals live. We are thus able to identify the key parameters more precisely.

Table 2
Internet exposure in adolescence and the risk of first marriage.

Variable	(1) Female	(2) Male
Internet infrastructure × Partly	-0.354	0.103
	(0.417)	(0.286)
Internet infrastructure × Fully	-1.702***	0.223
	(0.583)	(0.499)
Control variable	Yes	Yes
City characteristics × Birth year	Yes	Yes
City fixed effects	Yes	Yes
Birth year fixed effects	Yes	Yes
N	5577	6285

Notes: $*p < 0.1$, $**p < 0.05$, $***p < 0.01$. Standard errors are in parentheses and clustered at the city level. The key variables of interest are the interaction terms of an individual's birth cohort and internet infrastructure in 1999 before the policy implementation. The estimated coefficient is significant and negative for females in Column (1). In other words, women who experienced the upgrading of the fast internet in their adolescence tend to reduce their risk of entering first marriage and delay the formation of marriage. Specifically, compared with women who did not experience the expansion of the internet in their adolescence, for every 10 % increase in the proportion of fixed line phone users, the risk probability of entering the first marriage of women who fully experienced the expansion of fast internet (during their age of 12–18) decreases by 6.8 % ($e^{-1.702\times \log 1.1} - 1 = -0.068$). The estimate is significant at the 1 % level. In contrast, women who partly experienced the expansion of the internet during their adolescence had a 1.5 % lower risk of entering their first marriage ($e^{-0.354\times \log 1.1} - 1 = -0.015$). However, the estimate is not significant.

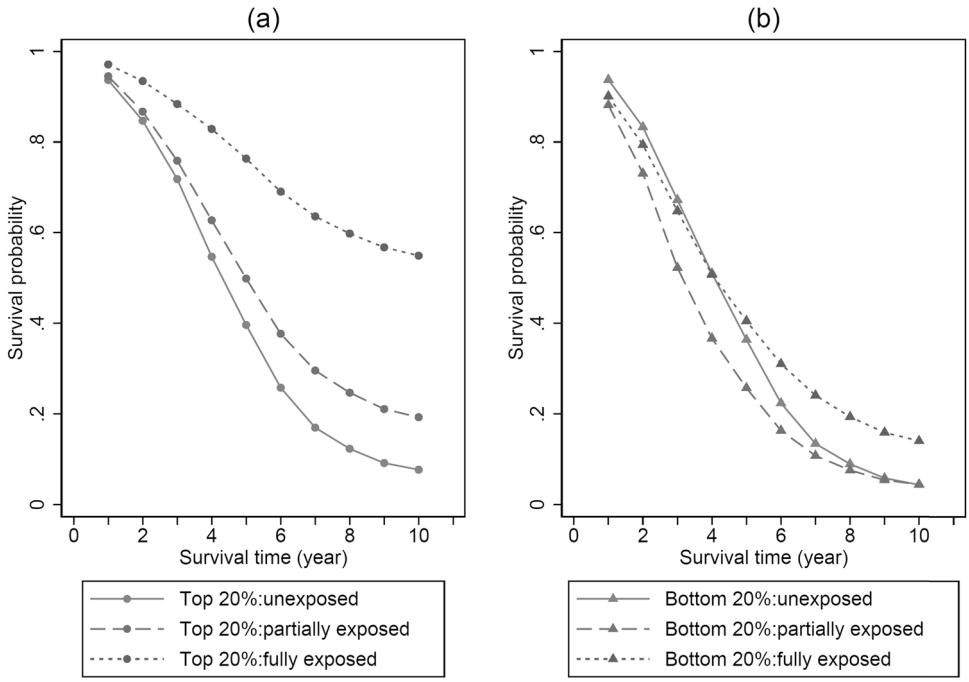

Fig. 2. Predicted survival probability. *Notes*: Fig. 2 presents the predicted survival probability of urban residence in a city with internet infrastructure (proportion of fixed line users) ranking among national top 20 % and the bottom 20 %.

Table 3
Robustness test: categorical variable of degree of impact.

Variable	(1)	(2)
Infrastructure × Partly	-0.354	
	(0.417)	
Infrastructure × Fully	-1.702***	
	(0.583)	
Infrastructure × Degree of impact		-0.768***
		(0.276)
Control variable	Yes	Yes
City characteristics × Birth year	Yes	Yes
City fixed effects	Yes	Yes
Birth year fixed effects	Yes	Yes
N	5577	5577

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors are in parentheses and clustered at the city level.

4. Empirical results

4.1. Baseline findings

Table 2 presents the estimated results of internet experience in adolescence on the risk of future first marriage by using the survival analysis model with Column (1) for a sample of females and Column (2) for a sample of males.[8] Each column controls for city fixed effect, the year of birth fixed effect, and a set of interaction terms between selected city pretreatment characteristics and birth year dummies. As stated in the research hypothesis, the current study mainly focuses on the impact of internet exposure on women's first marriage decision-making. Estimates for males are presented for comparison and completeness in Table 2.

For males, the estimated coefficients are not significantly different from zeroes. Compared with the effect of internet experience in the early stage, the sex ratio of men and women, city average wage and per capita GDP are significantly and negatively correlated with the age of first marriage in Column (2). This indicates that economic conditions have a larger impact on men's first marriage decision, while these factors are not significant for women in Column (1). The effect of housing prices in the city is not significant for either men or women in the sample of analysis.

As a tentative summary of the benchmark estimation, women's experience of fast internet expansion in adolescence significantly reduces the risk of their age at first marriage. In contrast, men are not affected. Therefore, in most analyzes in the following sections, we mainly focus on the female sample for robustness and mechanism discussions. Moreover, women who have fully experienced the expansion of fast internet are significantly more affected. This finding is consistent with our expectation that the earlier they are exposed to the fast internet, the more likely they are to change marriage decisions in adulthood. In the following event analysis, we further analyze and validate such findings.

Based on the estimated parameters in Table 2, we simulate the survival probability of women who have not experienced, partially experienced and fully experienced internet expansion from 19 to 30 years old. Panel (a) of Fig. 2 calculates the situation for urban women from regions with the top 20 % of internet infrastructure, and Panel (b) calculates the situation for urban women from regions with the bottom 20 % of internet infrastructure. Even after 10 years (age 30), the unmarried probability for women who fully experienced the expansion of fast internet in their adolescence is still very high, close to 0.6. In contrast, women in other regions, as well as women who have partly experienced or have not experienced fast internet expansion, have a low probability of remaining unmarried after 10 years.

4.2. Robustness checks

In this section, we conduct several robustness checks, including the use of alternative methods and define the impact on female adolescents from the expansion of fast internet, the definition of the age range of adolescents before the change of time analysis method, and the use of alternative measures of the development of internet infrastructure.

In the first robustness check, we use a categorical variable, degree of impact, to describe the intensity of influence on female adolescents from the internet expansion. In particular, we assign a value of 0 for women who did not experience internet expansion at all during adolescence, a value of 1 if they experienced internet expansion partially during adolescence, and a value of 2 if they experienced internet expansion completely during adolescence. Then, we multiply the degree of impact with the internet infrastructure in 1999 to form an interaction term as the independent variable of interest. The results are presented in Table 3 (Column (2)). Table 3 shows that the estimated coefficient of the newly constructed interaction term is negative and significant at the 1 % level.

Second, to evaluate the impact of internet expansion on the risk of first marriage at all ages of adolescence, we construct six dummy variables according to the individual year of birth to indicate (1) birth year of 1980 (i.e., two years post-adolescence at the time of fast

[8] A complete presentation of the results is available in Table A1.

Table 4
Robustness check: event study by birth cohort.

Variable	(1)
Infrastructure × Birth cohort 1981	-0.476
	(0.585)
Infrastructure × Birth cohort 1982–1983	-0.449
	(0.456)
Infrastructure × Birth cohort 1984–1985	-0.586
	(0.572)
Infrastructure × Birth cohort 1986–1987	-0.762*
	(0.397)
Infrastructure × Birth cohort 1988–1990	-1.949***
	(0.609)
Control variable	Yes
City characteristics × Birth year	Yes
City fixed effects	Yes
Birth year fixed effects	Yes
N	5577

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors are in parentheses and clustered at the city level.

Table 5
Robustness check: alternative measure of pretreatment internet infrastructure.

Variable	(1)
Infrastructure1997–1999 × Partly	-0.469
	(0.329)
Infrastructure1997–1999 × Fully	-1.457***
	(0.479)
Control variable	Yes
City characteristics × Birth year	Yes
City fixed effects	Yes
Birth year fixed effects	Yes
N	5577

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors are in parentheses and clustered at the city level.

Table 6
Internet exposure and the risk of first marriage by urban and rural areas.

Variable	Urban	Rural
Infrastructure × Partly	-0.598**	-0.070
	(0.252)	(0.510)
Infrastructure × Fully	-1.504**	0.337
	(0.695)	(0.550)
Control variable	Yes	Yes
City characteristics × Birth year	Yes	Yes
City fixed effects	Yes	Yes
Birth year fixed effects	Yes	Yes
N	3395	2055

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors are in parentheses and clustered at the city level.

internet expansion initiation); (2) birth year of 1981 (i.e., one year post-adolescence when internet expansion initiated); (3) birth year of 1982 and 1983 (i.e., 1–2 years experience of internet expansion during adolescence); (4) birth year of 1984 and 1985 (i.e., 3–4 years experience of internet expansion in adolescence); (5) birth year of 1986 and 1987 (i.e., 5–6 years experience of internet expansion in adolescence); and (6) birth year of 1988–1990 (i.e., a complete experience of internet expansion during adolescence). Among them, the cohort of birth year 1980 is used as the default reference group.

The estimated results are presented in Table 4. From the results, the closer the time of birth and the growth stage of teenagers are to the period of internet expansion, the stronger the effect on the age of first marriage is. These results also show that an experience of internet expansion in early adolescence is more likely to affect the age of first marriage in the future. Although experiencing the internet in late adolescence tends to reduce the risk of first marriage (for example, women born in 1984–1985, i.e., experiencing internet expansion at the age of 15–16), the estimate is not significantly different from zero.

Table 7
Internet exposure in adolescence and women's educational attainment.

Variable	Years of schooling	High school (1/0)	College (1/0)
Infrastructure × Partly	1.349	0.121	0.133
	(1.015)	(0.117)	(0.096)
Infrastructure × Fully	0.193	-0.054	0.040
	(1.140)	(0.133)	(0.124)
Control variable	Yes	Yes	Yes
City characteristics × Birth year	Yes	Yes	Yes
City fixed effects	Yes	Yes	Yes
Birth year fixed effects	Yes	Yes	Yes
N	1021	1021	1021

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors are in parentheses and clustered at the city level.

Third, we calculate the average proportion of fixed telephone users in prefecture-level cities from 1997 to 1999 as a new proxy of internet infrastructure and present the estimation results in Table 5. Compared with the benchmark results, the estimated coefficient is almost unchanged, which implies that the above results are not driven by the mismeasurement of internet infrastructure.

4.3. Heterogeneous analysis

Thus far, our estimates show that women who experienced fast internet expansion in their adolescence tend to reduce their risk of first marriage. In China, the dual division of urban and rural areas may make urban and rural residents encounter quite different resources and development opportunities. In the remaining part of this section, we perform heterogeneity analysis by splitting the female sample by the locality of rural and urban areas.

Table 6 presents the estimated results of women living in urban (Column (1)) and rural areas (Column (2)). The risk of future marriage among teenagers who experience the expansion of fast internet use is reduced by 2.4 % ($e^{-0.598\times \log 1.1} - 1 = -0.024$). The risk of first marriage for urban women who have fully experienced the expansion of the internet is reduced by 6.0 % ($e^{-1.504\times \log 1.1} - 1 = -0.060$). For rural female residents, the above estimates are not significantly different from zero. The results appear reasonable and supportive of the main findings of the paper because the proportion of fixed line telephone users in rural areas is very low approximately 1999.

5. Discussion of mechanisms

In this section, we scrutinize the possible underlying mechanism of prior findings of fast internet expansion on the first marriage decision of women according to the related literature and theoretical framework in Section 2.

5.1. Educational attainment

Prior studies show that women's education level is negatively correlated with the age of first marriage. The first underlying mechanism is that the internet experience in adolescence increases women's educational attainment and then their first marriage decision-making. On the one hand, internet expansion can enable teenagers to obtain more online education resources and improve their learning efficiency and human capital. On the other hand, the internet may also increase their online entertainment time, reduce learning time, and ultimately have an adverse impact on the acquisition of human capital. Based on the above analysis, the current paper constructs the following linear regression model (OLS) to measure the impact of internet experience in adolescence on women's educational attainment.

$$\begin{aligned} Educ_{i,c,p} = a + \beta_1 Infrastructure_{\,c,1999} \times partly_{i,p} + \beta_2 Infrastructure_{c,1999} \times fully_{i,p} \\ + X'_{i,c,p}\gamma + \eta_c + \kappa_p + W'_{c,1999} \times \kappa_p + \varepsilon_{i,c,p} \end{aligned} \tag{5}$$

Where $Educ_{i,c,p}$ represents the education level of women, and other variables are the same as those in Eq. (1). We use three indicators to measure women's education in adulthood in Table 7: years of schooling (Column (1)), ever entering high school (Column (2)), and ever entering college (Column (3)). After controlling for a series of personal characteristic variables, including Han nationality, parental education and urban residents, the estimated coefficient of the interaction terms variables of interest is not significantly different from zero in each of the three columns. Therefore, we exclude the education channel as a mechanism to explain the benchmark results in the prior section according to the results in Table 7.

5.2. Searching cost in marriage market

As described in Section 2, in addition to the expansion of the internet in 2000, China has opened gigabit broadband lines and upgraded bandwidth many times since 2000. These ICT infrastructure upgrades may affect the searching cost of adult women in the

Table 8
Controlling for the time-varying internet penetration.

Variable	(1)
Infrastructure × Partly	-0.357
	(0.420)
Infrastructure × Fully	-1.704***
	(0.585)
Internet penetration	0.0490
	(0.619)
Control variable	Yes
City characteristics × Birth year	Yes
City fixed effects	Yes
Birth year fixed effects	Yes
N	5577

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors are clustered in parentheses and clustered at the city level.

Table 9
Internet exposure in adolescence and gender identity.

Variable	Female Family happiness and harmony	Male Family happiness and harmony
Infrastructure × Partly	-0.428*	-0.098
	(0.224)	(0.172)
Infrastructure × Fully	-0.582***	-0.180
	(0.212)	(0.351)
Control variable	Yes	Yes
City characteristics × Birth year	Yes	Yes
City fixed effects	Yes	Yes
Birth year fixed effects	931	850

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors are clustered in parentheses and clustered at the city level.

marriage market, increase the matching efficiency of partners, and improve the marriage rate (Bellou, 2015; Kendall, 2011; Rosenfeld & Thomas, 2012). Of course, a reduction in searching cost and increase in marriage matching cannot explain the main findings in the current study. We consider it as a potential source of bias and conduct further analysis. In other words, the potential influence of searching cost may bias our prior estimates in Table 2 towards zeroes. To eliminate this concern, we add the internet penetration variable varying with time in each region to the model as the proxy variable of searching cost by following the general practice of the literature. This variable presents the level of using internet as a searching instrument. From the estimation results in Table 8, the coefficient of the explanatory variable of interest becomes − 1.704, which is consistent with the results of the benchmark regression. Table 8 indicates that the change in the searching cost in the marriage market may not change the long-term impact of the internet experience in adolescence on marriage decision-making.

5.3. *Gender identity*

Section 2 shows that internet may reshape adolescent's belief on gender identity and change their attitudes and behavior towards marriage. Gender identity represents how people view the social role orientation of men and women, for example, the "domestic wife and social husband," and "better for a woman to marry well than to work well." Therefore, gender identity norms reflect the gender egalitarianism of society to some extent. Recent studies show that gender identity norms may directly affect marriage matching patterns, family specialization, and labor supply (Akerlof & Kranton, 2000; Bertrand et al., 2021, 2015). The recognition of gender roles in the family largely reflects the openness of one's marriage concept. Women with a strong traditional gender identity have a stronger marriage tendency and higher marriage rate than women with a weak gender identity (Hartwell et al., 2014).

To the best of our knowledge, there are few questions related to the gender role of respondents in the CFPS dataset. We choose a proxy variable among the related questions available. Specifically, respondents grade on a scale of 1–5 according to the importance of the following concept to themselves: "happy and harmonious family", which "1" means "unimportant" and "5" means "very important." According to the scores of the question, we constructed a continuous variable to represent the degree of gender identity, with a higher value indicating a stronger confirmative attitude toward a traditional gender role. The econometric model used to measure the impact of internet experience in adolescence on women's gender identity is as follows.[9]

[9] The number of observations decreases because many women in CFPS did not answer the gender role related question. The results are regarded as suggestive evidence.

$$GI_{i,c,p} = a + \beta_1 Infrastructure_{c,1999} \times partly_{i,p} + \beta_2 Infrastructure_{c,1999} \times fully_{i,p} + X'_{i,c,p}\gamma + \eta_c + \kappa_p + W'_{c,1999} \times \kappa_p + \varepsilon_{i,c,p} \quad (6)$$

Where $GI_{i,c,p}$ represents the degree of gender identity. The construction of other variables is the same as those in Eq. (1). Comparing the regression results of female and male samples in Table 9, we find that women who fully experienced the expansion of fast internet in their adolescence have a more open marriage concept than their counterparts who did not experience the fast internet expansion (Column (1)). In other words, the internet experience in adolescence has changed a woman's traditional gender role attitude. A more egalitarian gender concept makes them more reluctant to follow the traditional gender role in a marriage. In contrast, men's attitudes toward family happiness and harmony do not change with internet expansion. The gender-specific results are consistent with our benchmark regression results and main findings.

6. Conclusion

In the context of the gradual increase in first marriage age and the continuous decline in fertility in China, the current paper uses the internet acceleration policy beginning in 2000 and identifies the impact of internet exposure in adolescence (12–18 years old) on first marriage decision-making in adulthood. We also scrutinize the possible underlying mechanism and generate the following conclusions.

First, internet experience in adolescence reduces the risk of first marriage among Chinese women. For every 10 % increase in the proportion of fixed line telephone users, the risk of first marriage of women who have fully experienced internet expansion (compared with women who have not experienced internet expansion in adolescence) is 6.8 % lower. The above effects are not significant for men. In the heterogeneity analysis, we find urban-rural differences in the effect of internet experience in adolescence on women's marriage delay. Women in urban areas are more sensitive to the impact of the internet.

Second, in the mechanism analysis, we excluded the impact of internet experience in adolescence on educational attainment and search costs in the marriage market. Suggestive evidence shows that internet experience in adolescence has changed women's traditional gender role attitudes and generated a more egalitarian gender concept and a more open marriage intention. It also makes women more reluctant to fit an expected traditional gender role in a marriage.

The current study has some implications. Prior studies suggest that the age of first marriage is very important for economic and social development. First marriage age affects the stability of marriage, which is particularly critical to the cultivation of children's human capital (Rotz, 2016). The age of marriage also affects the fertility rate of families (Cecos et al., 1982). Therefore, compared with the existing literature on the reasons for the formation of first marriage, the analysis perspective based on the internet experience in adolescence undoubtedly expands the understanding of women's first marriage delay in this field. In the context of China's declining fertility rate, we may need to pay attention to how digital technology shapes personal marriage intention.

The current research has some limitations. First, although the current paper provides supportive evidence that the shaping of teenagers' marriage concept by the internet indirectly affects the decision-making of first marriage (and excludes other potential mechanisms), our measurement of gender attitude is not comprehensive enough because of data limitations. Future research may explore a more comprehensive dataset and directly examine the impact of digital technology on gender attitudes and other social and cultural norms. Second, we identify the ITT (intention-to-treat) rather than TOT (treatment-on-treated) effects in the paper. We are short of information of individual's use of internet during his adolescent and marriage in adulthood. If such information is available, we may transform the ITT to TOT. We leave it as an extension for future exploration when the information is available.

Data Availability Statements

The datasets analyzed during the current study are not publicly available due to restricted access of the data set but are available from the corresponding author on reasonable request.

Declaration of Conflict of Interest

The authors declare that they have no conflict of interest.

Data Availability

The authors do not have permission to share data.

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Appendix A

See Appendix Table A1 here.

Table A1
Complete results of internet exposure in adolescence and the risk of first marriage.

Variable	(1) Female	(2) Male
Internet infrastructure × Partly	-0.354	0.103
	(0.417)	(0.286)
Internet infrastructure × Fully	-1.702***	0.223
	(0.583)	(0.499)
Han	-0.337*	-0.439
	(0.188)	(0.275)
Education attainment	-0.069***	-0.016
	(0.013)	(0.016)
Paternal education	-0.000	-0.018
	(0.012)	(0.014)
Maternal education	0.011	-0.008
	(0.010)	(0.012)
Studying in school	-2.028***	-1.803***
	(0.234)	(0.374)
Sex ratio	0.105	-0.097*
	(0.125)	(0.056)
Urban residence	-0.156	-0.253**
	(0.114)	(0.123)
Annual wage	-0.038	-0.011*
	(0.027)	(0.006)
Per capita GDP	-0.009	-0.013**
	(0.007)	(0.006)
Housing price	0.017	0.007
	(0.021)	(0.016)
$\delta 1$	0.654***	0.148
	(0.158)	(0.175)
$\delta 2$	1.397***	0.369**
	(0.239)	(0.184)
$\delta 3$	1.720***	0.626***
	(0.288)	(0.180)
$\delta 4$	1.883***	0.887***
	(0.359)	(0.233)
$\delta 5$	2.371***	1.010***
	(0.411)	(0.232)
$\delta 6$	2.555***	0.986***
	(0.500)	(0.264)
$\delta 7$	2.536***	0.639**
	(0.557)	(0.321)
$\delta 8$	2.707***	0.331
	(0.724)	(0.353)
$\delta 9$	2.433***	0.376
	(0.922)	(0.412)
City characteristics×Birth year	Yes	Yes
City fixed effects	Yes	Yes
Birth year fixed effects	Yes	Yes
N	5577	6285

Notes: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. Standard errors are in parentheses and clustered at the city level.

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