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How does digital finance impact birth rates: Evidence from China

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ABSTRACT

Digital finance (DF), the integration of tradition financial services and new information technology, has been shown to have various impacts in social behaviour. However, how DF affects people's fertility behaviour is still under investigation and worth exploring from the point of view of long-term economic growth. By employing a DF index, publicly available city-level birth rates in 287 Chinese cities, we find DF has a negative influence on birth rates. This finding is supported by endogeneity and several robustness tests. Mechanism tests show DF increases investment opportunities and therefore reduces the need of having children for support in old age. DF increases consumption and possibly individualism and also increases women's economic independence and their opportunity cost of having children, leading to lower birth rates. Given the development of DF is an inevitable trend, we further find that out of the three components of DF index measures, the coverage of DF significantly decreases birth rates, while the higher level of DF development, depth and digitalization, have much less negative impact on birth rates. Finally, this negative impact can be moderated when governments make policy efforts to increase educational and medical resources and provide protection of religion. This paper provides a novel perspective on the influence of DF on social behaviour through DF's direct impact on investments, consumption and income.

"It's not a faith in technology. It's faith in people."

Steve Jobs

1. Introduction

With the deep integration of information technology and traditional finance, digital finance (DF) has developed rapidly in recent years, especially in China. This new finance technology is gradually becoming an integral part of China's financial system (Mu et al., 2023). At the same time, the low birth rate and the disappearance of the demographic dividend are becoming serious problems for the Chinese economy (Peng, 2011). Boserup's (1976) theory of the demographic transition emphasizes the crucial importance of endogenous technological shifts in population change. For example, Dettling (2017) finds that high-speed internet use leads to a 4.1 percentage point increase in labour force participation for married women, which in turn shapes fertility decisions. Also, Billari et al. (2020) find that mobile phone acquisition is associated with reductions in family size and reduces the demand for children through role change from family-oriented to career-oriented and preference changes. Given China's serious fertility dilemma and the gradual

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prevalence of digital financial services, it is important to explore whether financial technology has an impact on birth rates.

DF is the organic integration of traditional finance services and new technology science (Wu, 2023). According to the research report released by the Institute of Digital Finance Peking University, China's DF business has grown by leaps and bounds between 2011 and 2020, with the median value of the provincial DF index at 33.6 in 2011, growing to 214.6 in 2015, and further to 334.8 in 2020. The median value of the DF index at the provincial level in 2020 is 10 times higher than that of 2011, and the index value is growing by 29.1 % per year on average. The above statistics show the rapid development trend of DF in China[1].

Studies have found DF can increase financial service coverage and financial products for investors, thus providing alternative investment opportunities and insurance for households to secure their future (Ji et al., 2021). Also, DF could ease liquidity constraints and boost consumption (Zhu et al., 2023) and possibly increases individual instant satisfaction and adherence to individualistic values (Preston, 1986; Sun and Ryder, 2016). Third, DF is an innovative financial tool that could increase the possibility of people, especially vulnerable groups such as women, benefiting from financial services; and could help women participate in entrepreneurship and financial markets and have access to more financial resources at lower cost, which gives women a stable income and equal status in the family (Han et al., 2023). However, papers have seldomly linked these impacts (the changing economic behaviour of households and family's structure) to further fertility decisions.

Since 1949, China has recognised the importance of population as a factor contributing to productivity, and thus fertility was encouraged. This provided a huge demographic dividend for China's development in the wake of reforms and the opening-up policy (Fang et al., 2018). However, with the emergence of overpopulation, unemployment and related social problems, China began to implement a one-child policy in 1982. In 2015, because of low birth rates, China liberalised its one-child policy and began implementation of the two-child policy. According to the National Bureau of Statistics of China (NBSC), birth rates after the liberalisation of fertility policies were only 12.64 ‰ in 2017, compared with 16.57 ‰ in 1997. Recent figures from NBSC have raised even more concerns. Birth rates in 2020 in China were 8.52 ‰, falling below 10 ‰ for the first time. In 2022, the natural population growth rate was -0.60 ‰, turning negative for the first time, and China dropped from first to the second largest country in terms of population. According to the latest data for 2023, the rate continues to fall and has dropped to −1.48 ‰.

Previous evidence shows that DF improves financial services and products, increases consumption, and increases women's economic independence (e.g. Ji et al., 2021; Liu and Hu, 2013; Han et al., 2023), while on the other hand these positive direct economic impacts could potentially negatively impact social behaviours such as birth rates, and therefore harm economic development from a long run perspective. We predict that DF may have a negative impact on birth rates through reduced fertility willingness for the following three reasons.

First, increased investment opportunities could lead to a decrease in the birth rate as there is less need to rely on children as a form of old-age security (Lan et al., 2023). Second, DF increases consumption and individualism, and we suggest this may reduce people's willingness to have children, as predicted by the theory of planned behaviour (Ajzen and Klobas, 2013), as the spread of secular individualism weakens people's long-term planning behaviour including fertility willingness (Luo and Mao, 2014; Sun and Ryder, 2016). Third, as society assigns to women the major responsibility of raising children, fertility is costly to women (Grossbard-Schechtman and Mincer, 2003) and exacerbates inequalities in the family. An increase in time and energy invested in having children reduces the corresponding effort expended on paid work, which has a negative impact on women's career development and reduces their economic independence. DF would give women more opportunity for economic gain and at the same time increase the opportunity cost of women having children. DF provides women with more bargaining power (Han et al., 2023) due to increasing economic independence that enables them to choose to work on career development rather than raising children.

In this study, we develop a model to empirically examine the relationship between DF and birth rates using a panel of data on 287 cities in China. We primarily choose China in our research setting due to the following considerations. First, data availability in China is a huge advantage. Benefiting from the DF index published by the Peking University, we can easily measure the adoption of financial technology at the macro level in China. Second, as one of the fastest-growing economies in the world, China exemplifies both the rapid rise of DF and the significant decline in birth rates, and many other countries are experiencing one or both of these trends. Studying China provides valuable insights on the relationship between digital finance and fertility trends which may be of interest to other markets, with similar trends of fast development of DF or pronounced decline in birth rates or both; and provide the policy implications. Last but not least, the role of DF in promoting women's economic independence and bargaining power (Han et al., 2023) may change family structures and have significant economic impacts. Similar dynamics may also exist in other countries, especially in emerging economies, where rapid financial digitalization reshapes household structures.

In our paper, we find that DF has a negative effect on birth rates in lagged, current and forward periods. To address potential endogeneity concerns, we introduce the 2SLS-Instrumental Variable (IV) approach. Previous literature has shown that the distance from a given city to Hangzhou is a good IV for DF (e.g. Zhu et al., 2023), as Hangzhou is the birthplace of Alipay, which is a leader in DF development in China. However, distance does not change over time, which invalidates the second-stage estimation as an instrumental variable. Following Zhang et al. (2020), we therefore interact the instrumental variable with the mean of the DF index at the national level (except for the specific city) as a new instrumental variable with time-varying effects to capture the exogenous variation in DF. Second, given the strong relationship between communication infrastructure and the development of DF (Chen and Zhang, 2021), we use the number of Internet users in year *t-1* times the number of fixed-line telephones per 100 people per city in 1984 as the second IV in the model.[2] The IV-2SLS test results are consistent with our baseline findings.

[1] Data is publicly available from https://idf.pku.edu.cn/yjcg/zsbg/513800.html

[2] We thank an anonymous reviewer for this recommendation.

The biggest challenge of this study is to explain how DF could impact birth rates. We explore several potential channels and conduct heterogeneity analysis based on the financial institution coverage and commercial insurance purchases; consumption level and ethnic groups; disposable income level and gender equality. The empirical results show that the baseline negative relationship is more pronounced when financial institutions' coverage and insurance purchased are high, indicating that wider use of financial services and financial products could reduce the need for children to financially support their parents in their old age. Second, DF decreases birth rates more significantly in areas with higher consumption and in non-ethnic minority areas.[3] High consumption could lead to individualism (Ahuvia, 2002) and weaken people's long-term fertility planning, while non-ethnic minority areas are more likely to be affected by individualism, as traditional values are weaker and one-child policy was strictly implemented in these areas. Third, the negative impact of DF on birth rates is more pronounced in more developed areas with a higher disposable income and areas with more gender equality, where women would have more economic independence, a higher opportunity cost for fertility and a stronger voice. In this case, more women would choose to have no or fewer children. The heterogeneity test results further deepen our understanding of the relationship between DF and birth rates and its underlying mechanisms.

Taking advantage of a DF index ranking system, following Ren et al. (2023), we further investigate the different impacts of the sub-categories of DF on birth rates. We find that although DF coverage that represents a significant degree of penetration or popularity significantly decreases birth rates, further development of DF depth and digitalization has a less negative impact on birth rates. These findings hint at a positive message that further developments in DF depth and digitalization would not reduce birth rates significantly.

Finally, we explore the factors that could moderate the negative relationship between DF and birth rates, given DF development is a non-stoppable trend. As proposed in the socioeconomic theory, restricted fertility is a means to enhancing children's chances of social upward mobility (Greenhalgh, 1988). Fertility is considered to be a type of investment and families could face high pressures in relation to child-raising (Lin and Kamo, 2015). We provide empirical evidence that the government's efforts to reduce the burden of raising children through increased educational and medical support and to protect people's fertility willingness by protecting religious belief, could moderate the negative effect of DF on birth rates.

The novelty of this paper lies in its comprehensive approach to examining how DF affects birth rates and providing an integrated analysis that bridges policy intervention and cultural dynamics, offering a more holistic understanding of fertility. Close to our study, Xie et al. (2025) use the data obtained from the China Household Finance Survey (CHFS) to study the impact of DF on family size and the age at first childbirth. They find DF has a modest positive impact on the household fertility rate. The variable of fertility is measured as the total number of unmarried children in a household, and they argue that a higher number of unmarried children indicates a greater fertility intensity within the household. While it is valuable to use household survey data in Xie et al. (2025), we question the accuracy of using the number of unmarried children in a household as a measure of fertility intensity. The age of unmarried children varies from 0 to over 30 in general, given the low marriage rate and the delay of the age of entering a marriage in China (Wrenn et al., 2019).[4] When we investigate the impact of DF, which has been a new development in the last 15 years, on fertility, the time period of DF development (last 15 years) and number of unmarried children (last 30 years) will not exactly match. The number of unmarried children is affected by the preference of the age of getting married or that of whether to marry or not as well. Therefore, the positive association between DF and the number of unmarried children in a household in Xie et al. (2025) might be an indication of the positive relationship between DF and the age of marriage, rather than that between DF and fertility rate. In addition, Lan et al. (2023) use provincial-level fertility data and find DF leads to higher fertility intentions. However, the variations of provincial-level fertility data are not as rich as city-level fertility data in our study. To our knowledge, we are the first to test the impact of DF on fertility behaviours using city-level birth rates in China. Our approach employs the city-level birth rate data, which we consider to be a more economically meaningful and comprehensive reflection of fertility trends (Gauthier and Hatzius, 1997).

This study contributes to the literature in the following ways. First, as DF continues to evolve rapidly, its influence could extend beyond economic activities to broader social behaviours. Previous evidence shows that DF improves financial services and products, increases consumption, and increases women's economic independence. However, these positive direct economic impacts could potentially negatively influence social behaviours such as birth rates, and therefore harm economic development from a long run perspective. Policy makers need to be aware of the potential challenges related to fast development of DF, and understanding its impact on birth rates is both academically valuable and policy relevant. To the best of our knowledge, we are the first to examine the impact of DF on birth rates at the city level in China. Our study provides a new perspective for understanding the impact of DF on social behaviour and long-term economic development and is a timely addition to the literature in this field.

Second, though empirical evidence shows DF reduces birth rates, our findings show policies such as increased government investment in healthcare and education recourses and protection of religious belief can mitigate the negative impact of DF on birth rates. Our evidence also shows that the first level of DF development (coverage) has the most negative impact on birth rates, while the further development of DF in terms of depth and digitalization has a much weaker negative impact. Our study highlights the importance of government medical and education support, freedom of religious belief and a shifting policy focus in DF development from coverage to

[3] There are 56 ethnic groups in China, of which the Han group makes up the vast majority, while the remaining 55 ethnic groups account for less than 10 % of the total population and are known as ethnic minorities. The ethnic people mostly live in the western provinces.

[4] The study "Postponement of Marriage and Childbearing in China during 1990-2020: Trends and Characteristics" examines national census and sampling survey data to explore the patterns of delayed marriage and childbirth. According to the findings, the average age at first marriage in China rose from 22.87 years in 1990 to 28.67 years in 2020. Additionally, the proportion of unmarried individuals at age 30 grew significantly over the past three decades. While only 4.82% of people remained unmarried at 30 in 1990, this figure surged to 21.75% by 2020, reflecting a notable change in marriage patterns. https://www.chinadaily.com.cn/a/202310/16/WS652ca3daa31090682a5e8c09.html?utm_source

depth and digitization on mitigating the negative impact of DF on birth rates. These findings have impactful policy implications with respect to fertility encouragement and further DF development.

The structure of this paper is as follows. Section 2 reviews the relevant literature and theoretical background and presents the hypotheses. Section 3 introduces the design of the research, including data, sample construction and empirical models. Section 4 describes the empirical results, and we make conclusions and discuss the policy implications of this study and potential future research in Section 5.

2. Literature review, theoretical background and hypothesis development

2.1. Digital finance and its impacts

Researchers have conducted a large number of studies on DF and its impact (e.g. Wu, 2023; Xiao et al., 2023). At the macro level, Ren et al. (2023) show that DF promotes industrial structure upgrading through innovation, entrepreneurship and the structure of household consumption, for example through more expenditure on services and goods such as healthcare and entertainment. Regional economic resilience (RER) is a hot topic after COVID, that studies how an economy can cope with external shocks and promote sustainable development (Kass-Hanna et al., 2022). Yu et al. (2023) show that DF not only strengthens local RER but also has a positive impact on neighbouring areas with positive spatial externalities. Moreover, digital technologies can break down geographical boundaries and generate utility spillover across regions. Environmental sustainability is also a characteristic of digital technology; it has been shown that DF decreases air pollution and carbon intensity through the adoption of online services and systems (Wang and Guo, 2022; Lee and Wang, 2022).

In terms of corporate finance, previous literature finds DF to be advantageous in improving firms' ESG performance by mitigating financial constraints within firms in China (Mu et al., 2023). The effect is more pronounced in non-state-owned enterprises (non-SOEs), small-sized firms and firms located in the central and western regions. In terms of firm resilience, Xia et al. (2022) show that firms located in regions with higher levels of DF experienced fewer losses and recovered more quickly from the COVID-19 pandemic, since DF helped firms by facilitating access to external financing and reducing financing costs. Xia et al. (2022) also document the positive effect is more significant in small firms and non-SOEs. Other studies such as Ding et al. (2022) find DF fosters firms' innovation performance by stimulating digital transformation of firms and improving innovation efficiency (Wang and Liu, 2024). DF also diversifies bankruptcy risk by improving firm information transparency and moderating financial leverage (Ji et al., 2022).

While most of DF impacts at the macro level and corporate levels are positive, its impact at the micro level is mixed. On the one hand, there have been many explorations of the impacts of DF at the micro level, such as promoting personal consumption (Li et al., 2020) and stimulating household online purchases (Zhu et al., 2023). DF provides great convenience for shopping by improving payment convenience and easing credit constraints, which has reshaped an emerging consumer model (Setiawan et al., 2022). More importantly, evidence has been found that DF could improve household income and encourage investment participation by reducing the cost and expanding the channels of financial services (Ji et al., 2021; Li et al., 2020). DF can easily overcome the shortage of traditional financial services and effectively penetrate areas where traditional services are under-supplied (Shen and Ren, 2023). A recent study by Han et al. (2023) shows that, because of its inclusiveness, DF can enhance women's bargaining power and alleviate intra-household inequality, because women are able to participate in financial markets at a lower cost and their financial situation is improved. They also show that DF encourages women's entrepreneurial behaviours, which enhance their bargaining power and status. On the other hand, Meng and Xiao (2023) find that taking advantage of DF, consumers' undesirable borrowing and spending behaviours boom, which are negatively associated with their happiness because of the consequent heavy debt burden.

2.2. Birth rate and its determinants

The extant literature (e.g. Yang et al., 2022; Lin and Kamo, 2015) finds that birth rates are affected by economic development and levels of education. Also, the increasing participation in the labour market has further intensified the competition for jobs, which in turn erodes people's free time. Increasing competitive pressures and physical pain make child-raising less attractive to the younger generation (Yang et al., 2022). Furthermore, education has a critical impact on fertility, especially for women. With higher education, the price of child-raising increases for women due to higher opportunity costs because of the sacrifice of career development (Lin and Kamo, 2015). Also, when women have more resources, due to higher educational and occupational attainment, they have more income and opportunities, so the appeal and fulfilment of marriage and parenthood is significantly reduced (Blair and Madigan, 2021). In addition, Zhang and Goza (2006) show that the rising proportion of older people has an impact on the fertility choices of newlyweds.

Birth rate levels largely rely on fertility intentions (Ajzen and Klobas, 2013), since the intentions affect a couple's planning process in their life cycle. Luo and Mao (2014) discuss the discrepancy between fertility intention and fertility behaviour in terms of the Theory of Planned Behaviour (TPB), and discover people tend to think rationally and practically when making child-raising decisions in the face of modernization. Attitudes concerning intimate relationships within modernized societies are more likely to reflect developmental idealism and place greater emphasis upon such qualities as prompt individual satisfaction, attention to personal needs, and the expression of self (Blair and Madigan, 2021). Technology also affects birth rates. For example, evidence has been found that internet and mobile phone usages shapes fertility decisions by increasing women's labour market participation (Dettling, 2017; Billari et al., 2020). It is thus reasonable to expect that DF as a new technology may affect people's fertility decisions.

2.4. Hypothesis development

On one hand, DF may stimulate fertility and increase birth rates. The information asymmetry theory (Aboody and Lev, 2000) refers to a situation where one party in an economic transaction has more or better information than the other party. This often leads to inefficient outcomes in markets because the less-informed party cannot make fully rational decisions. It helps explain how DF reduces financial uncertainty by improving income and financial services information, potentially influencing household fertility decisions. By lowering barriers to financial information and access, DF can reshape individuals' expectations about future income and economic security. Second, digital platforms make it easier for families to access government subsidies, healthcare support, or maternity benefits. Thus, better information flows reduce the cost and uncertainty associated with accessing these resources, which in turn may increase their willingness to have children and increases overall birth rates in the long run. Lan et al. (2023) find that digital financial inclusion can enhance household income, lower financial service costs, and ease liquidity constraints. Thus, the cost of child-raising will be decreased, leading to higher fertility intentions, especially for financially disadvantaged families. Therefore, we propose the following hypothesis:

H1a. *DF has a positive impact on birth rates.*

On the other hand, DF may decrease birth rates for the following reasons. First, DF provides alternative investment opportunities for households trying to secure their future. Taking advantage of DF, households have easier access to financial markets and enjoy the services at a lower cost. Li et al. (2020) find that DF can help households find better ways to secure themselves financially, such as buying financial products and commercial insurance, as DF breaks down the geographical barriers of the offline mode and improves accessibility to insurance services. Increased financial services and products provided by DF would reduce birth rates, as there is less need to rely on children as a form of old age financial security.

Second, according to the financing constraint theory (Hall et al., 2016), individuals may face limitations in accessing external funds due to information asymmetries, or underdeveloped financial markets. These constraints lead to limited future investment and sub-optimal decisions. DF can ease liquidity constraints (Li et al., 2024) by improving access to credit. However, greater financial flexibility does not always translate into greater economic benefits (Hottenrott and Peters, 2012) and reduced liquidity constraints may over-simulate consumption and alter the household financial planning process, and it can also lead to greater financial burden and risk exposure (Meng and Xiao, 2023). The increased financial and debt burdens due to better financing ability may shift household priorities and discourage childbirth. Also, DF often comes with increased exposure to consumption aspirations (Li et al., 2020) and potential social comparisons among households. This may raise the perceived cost of childrearing, as parents feel pressure to provide a higher standard of living for their children. In addition, the excessive intermediate consumption caused by DF would induce a stronger sense of individualism and encourage immediate spending (Karlan and Zinman, 2010), leading to negative feelings about raising children in the long run and therefore lower birth rates.

Third, previous studies find that fertility hinders women's career advancement and financial freedom in the modern world (e.g. Ebenstein, 2010; Grossbard-Schechtman and Mincer, 2003), as they have to give up more working hours and job opportunities in order to raise and care for their children. This further exacerbates the unequal status of women in the family (Cherchye et al., 2009). A recent study by Han et al. (2023) finds that higher DF adoption contributes to higher participation by Chinese women in entrepreneurial endeavours and financial markets and thus improves women's economic strength and bargaining power and alleviates intra-household inequality. As women's career opportunities and participation in the labour market increases, they may forego having children, as raising children incurs high opportunity costs for women's income and social success (Grossbard-Schechtman and Mincer, 2003).

Based on the discussion above, we propose our second hypothesis:

H1b. *DF has a negative impact on birth rates.*

Relevant literature based on socioeconomic theory suggests that restricted fertility is a means to enhancing children's chances of social upward mobility (e.g. Greenhalgh, 1988). Raising children can be viewed as a type of investment (Lin and Kamo, 2015). As the standard of living rises, the dimension of household investment in children increases, including physical capital such as property, and human capital such as education and health (Bryant, 2007). Moreover, there is a lot of pressure on the couple to become "responsible parents" (Doherty et al., 1998). Previous literature points out that the long-term patterns of economic growth increase the socially constructed "costs" of raising children and the opportunity costs of pursuing a lifetime of responsible parenthood, producing a long-term fertility decline (Preston, 1986).

In addition, studies find that social norms have a significant influence on fertility intentions (Yu and Liang, 2022). The traditional Chinese culture emphasizes harmonious relationships with family compared to individualistic cultures, but regional differences in fertility culture also exist (He et al., 2019; Wang et al., 2022). Studies also find that people with religious beliefs place a higher value on the perpetuation of the family line (Wan et al., 2021).

We contend that government policies aimed at reducing fertility-related stress through enhanced access to educational and medical resources and promoting positive social norms around parenthood can effectively strengthen individuals' intentions to have children.

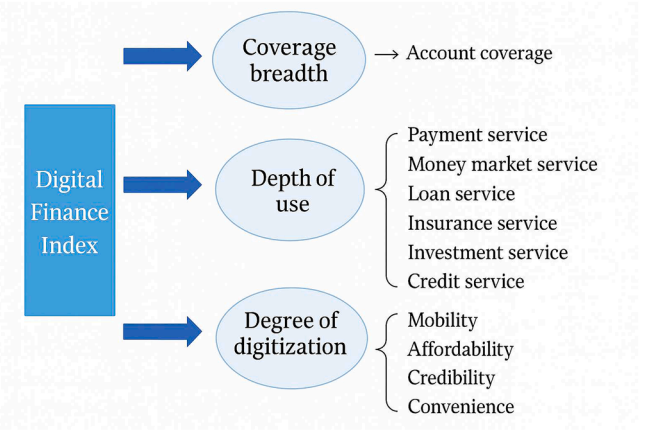

Fig. 1. The index system of digital finance.

Table 1
Summary statistics.

Variables	Obs.	Mean	Std.	Min	Max	Skewness	Kurtosis
Birth Rate (‰)	822	12.406	4.236	4.191	25.041	0.683	1.066
DF	822	2.335	0.230	1.935	2.979	0.635	0.384
Marketization	822	0.877	0.041	0.775	0.950	−1.526	8.310
Road	822	2.870	0.391	1.552	3.663	−0.532	1.417
GDP	822	10.577	0.842	8.245	12.165	−0.648	0.602
Unemployment	822	0.031	0.005	0.022	0.042	−0.001	−0.570
AQI	822	4.323	0.247	3.801	4.824	−0.073	−0.604
Education	822	8.540	0.580	6.480	9.388	−1.533	4.603
Beds	822	3.795	0.359	3.001	4.596	0.203	−0.036
Elder	822	0.167	0.034	0.103	0.238	−0.004	−0.633
Unmarried	822	0.184	0.332	0.133	0.268	0.730	0.125
Institution	822	1.649	0.302	1.154	2.345	0.700	−0.300
Loan	822	8.748	0.638	7.798	12.271	2.534	11.412
Gender	822	1.046	0.045	0.967	1.181	1.186	1.737
Internet	822	12.271	0.893	9.944	14.137	−0.383	0.210

This table shows summary statistics of main variables. Detailed definitions of variables are reported in the Appendix.

3. Research design

3.1. Data source, variables and summary statistics

Taking the advantage of the announcement of birth rates of Chinese cities in the 2017–2019 Statistical Yearbook,[5] panel data on 287 Chinese cities is used as the basis of the sample. The city level birth rate information is obtained from the Statistical Yearbook of Chinese cities. The main independent variable, the DF index, is published by the Peking University and has been widely used in many empirical studies (e.g. Mu et al., 2023). The ranking system of the DF index consists of three second-level indices, namely the index of coverage breadth (*Coverage*), the index of use depth (*Depth*) and the index of degree of digitization (*Digit*). The breadth of coverage is reflected in the number of Alipay accounts owned and the number of bank cards per capita on the mobile phone applications. Coverage measures how widely DF is used. Depth of use measures the actual use of online financial services such as online payment, insurance, investment, credit loan and investigation services. Degree of digitization focuses on the higher mobility, affordability and convenience of digital financial services. Fig. 1 depicts the construction of the DF index system.

Existing literature finds that economic and social development provides more employment opportunities, which in turn inhibits fertility growth (Myrskylä et al., 2009). As shown in Carré et al. (2017), air pollution also decreases fertility. Martin (1995) uses evidence from 26 demographic and health surveys to show that education enhances women's ability to make reproductive choices and that highly educated women have the lowest fertility intentions. Also, shortage of medical resources and pressure resulting from providing elderly care exacerbates the decline in household fertility rates (e.g. Zhang and Goza, 2006). There is also evidence that children born to unmarried parents are discriminated against in China (Palmer, 1995). Moreover, reducing the cost of financial services and alleviating financial constraints can encourage fertility intentions (Lan et al., 2023). Additionally, the development of DF is

[5] This city level data is publicly available in these three years.

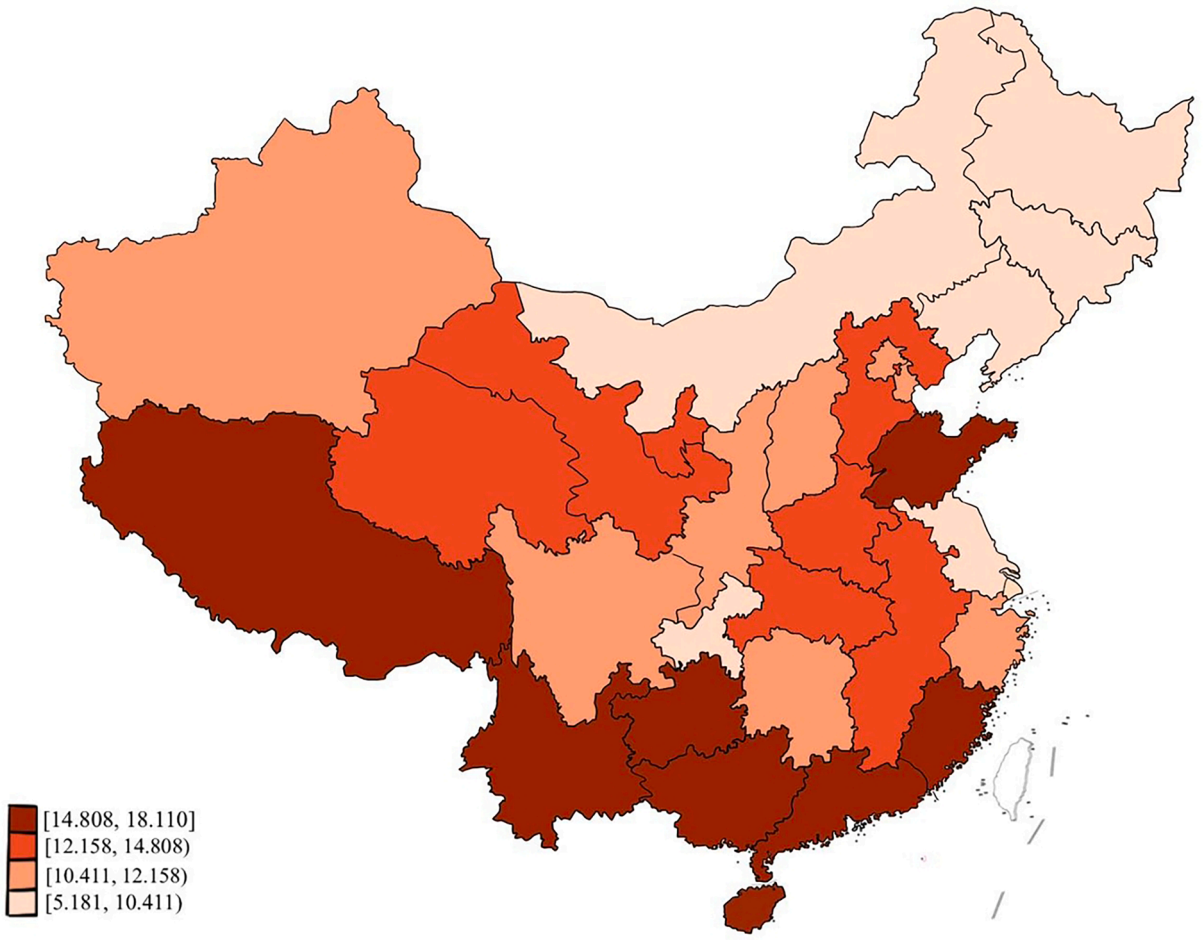

Fig. 2. Birth rate heat map of China.

influenced by the progress of the digital economy (Chen and Zhang, 2021). Thus, we introduce the following control variables: the level of marketization (*Marketization*), infrastructure level (*Road*), economic development (*GDP*), the rate of unemployment (*Unemployment*), air pollution level (*AQI*), regional education level (*Education*), medical bed facilities (*Bed*), aging population (*Elder*), marital status (*Unmarried*), the coverage of financial institutions (*Institution*), the scale of bank lending (*Loan*), the regional gender ratio (*Gender*) and the level of development of the digital economy (*Internet*); definitions are provided in Appendix. These variables and other relevant data in the sample are retrieved from NBSC and the China Stock Market & Accounting Research database (CSMAR).

Table 1 shows the mean, standard deviation, minimum and maximum value, skewness and kurtosis of the main variables that we use to assess the distribution of the economic data (Andrei et al., 2010). The mean value of birth rate is 12.406 ‰, which is historically very low, reflecting the negative concepts of fertility of contemporary Chinese couples. The mean level of the DF index is about 2.335, with a standard deviation of 0.230, indicating the development of DF still varies greatly from city to city. The distributions of other control variables are consistent with previous findings (e.g. Shen and Ren, 2023; Han et al., 2023; Yang et al., 2023). The final sample consists of 822 observations and we winsorize all city-year continuous variables at the 1st and 99th percentiles to mitigate the effect of outliers.

The heat maps in Figs. 2 and 3 represent the average birth rate and DF index in each province of China.[6] The darker the colour, the higher the variable value. Provinces with higher birth rates (shown in red) are more concentrated in the southwestern regions, where minority ethnic groups reside. DF technology is more developed in the eastern coastal provinces (shown in blue). Overall, both figures indicate very large variations in the key variables across different regions.

Furthermore, we check whether independent variables included in the same model are highly correlated. This step is fundamental because multicollinearity could bias estimated results. As shown in the Table 2, the highest correlation coefficient registered between

[6] Due to the data availability, we only include 27 provinces and 4 municipalities directly under the Central Government which are Beijing, Shanghai, Tianjin, and Chongqing.

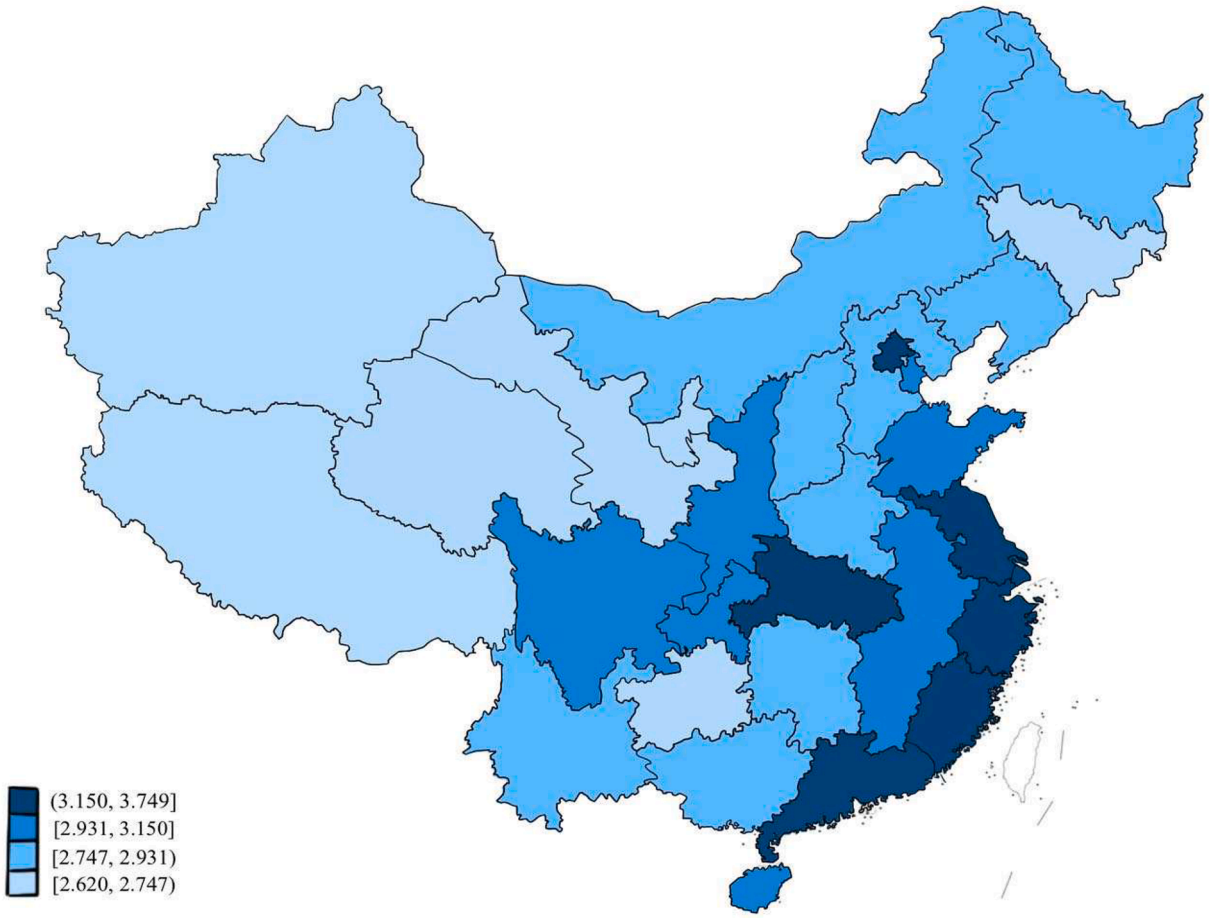

Fig. 3. Digital finance index heat map of China.

two independent variables included in the same econometric model is reported between GDP and DF as 0.770. According to Batrancea et al. (2023), correlations below 0.8 indicate no multicollinearity issues. Following literature, multicollinearity is further investigated for each econometric model with the help of the variance inflation factor (VIF). In all cases, the VIF values are lower than 4, which is below the standard cutoff value of 10 suggested in the literature (Batrancea et al., 2022). Since there is no multicollinearity risk for our econometric models due to the low VIF values, we conclude that multicollinearity would not bias the econometric estimations.

3.2. Regression model settings

We develop the following regression model to estimate the impact of DF on birth rates:

$$BR_{i,t} = \beta_0 + \beta_1 DF_{i,t} + \beta_2 Control_{i,t} + city_i + year_t + \varepsilon_{i,t} \quad (1)$$

where the subscripts i and t represent city and year, respectively. BR represents the birth rate of city i in year t. DF represents the digital finance index in year t in the city i, which is measured by the level of digital finance development. $Control$ denotes control variables and ε is the random error term. We conduct the Lagrange Multiplier (LM) test, F test and Hausman test where we find that the panel data provides the best fit with a fixed effects model. We then control the year fixed effect and city fixed effect in the model. We also conduct the panel cointegration test and Im-Pesaran-Shin unit root test. Based on the current short sample period, time trend between variables cannot be effectively identified and our regression results are not driven by the cointegration, or an estimated panel data regression contains a unit root.[7]

[7] Results can be provided upon request. We thank an anonymous reviewer for advice of performing these tests.

Table 2
Correlation matrix and VIF test.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	VIF
1. DF	1.0000														4.45
2. Marketization	0.3940	1.0000													3.16
3. Road	0.1312	0.0367	1.0000												1.30
4. GDP	0.7702	0.1577	0.1326	1.0000											3.24
5. Unemployment	−0.3037	−0.2075	−0.1409	−0.1494	1.0000										2.24
6. AQI	0.0463	0.0530	0.1401	0.0208	0.0797	1.0000									1.47
7. Education	0.2716	0.6536	0.0343	0.1507	−0.1027	0.2458	1.0000								4.59
8. Beds	0.4894	−0.0795	−0.1987	0.5359	0.2066	0.0701	−0.0309	1.0000							2.63
9. Elder	0.0806	0.0884	0.1240	0.1174	0.2706	0.3212	0.3980	0.1215	1.0000						3.61
10. Inmarriage	−0.0425	−0.0231	−0.1510	−0.1046	−0.5386	−0.3352	−0.1747	−0.2023	−0.6935	1.0000					3.14
11. Institution	0.0155	−0.0663	−0.1064	0.0715	0.3871	0.0464	−0.1359	0.3277	0.0459	−0.3131	1.0000				1.90
12. Loan	0.3485	0.0445	−0.0728	0.3333	0.0039	−0.1252	−0.3375	0.2878	−0.1742	−0.0220	0.4985	1.0000			2.39
13. Gender	0.2318	0.3607	−0.0090	0.0571	−0.5291	−0.3532	0.1110	−0.2011	−0.6052	0.5913	−0.1975	0.0976	1.0000		3.31
14. Internet	0.4703	0.2733	0.1139	0.4510	−0.3176	−0.0644	0.5683	−0.0181	0.2673	0.0040	−0.2077	−0.1133	0.2250	1.0000	1.30

Table 3
Baseline results.

Variables	(1) Birth Rate	(2) Birth Rate	(3) Birth Rate$_{t+1}$	(4) Birth Rate$_{t+1}$	(5) Birth Rate	(6) Birth Rate
DF	−10.856***	−10.938***	−9.792***	−5.669**		
	(−4.302)	(−3.535)	(−3.286)	(−1.988)		
L.DF					−9.792***	−9.070**
					(−3.286)	(−2.588)
Marketization		10.127		−27.320*		−11.232
		(0.811)		(−1.929)		(−0.896)
Road		0.386		−0.839		0.086
		(0.565)		(−1.615)		(0.118)
GDP		−0.163		−0.150		1.532
		(−0.574)		(−0.998)		(1.275)
Unemployment		−91.373**		−271.141***		−94.255*
		(−2.095)		(−5.728)		(−1.953)
AQI		−0.475		−1.889		0.331
		(−0.290)		(−1.423)		(0.121)
Education		−0.652		0.742		−0.635
		(−0.612)		(0.819)		(−0.379)
Bed		−0.045		0.284		−0.943
		(−0.032)		(0.248)		(−0.631)
Elder		−22.829		−22.837**		116.414***
		(−1.235)		(−2.555)		(3.577)
Unmarried		5.424		−13.561		9.555
		(0.472)		(−1.262)		(0.736)
Institution		−0.083		−1.742		1.607
		(−0.060)		(−1.325)		(0.679)
Loan		−3.530*		0.692		2.652
		(−1.924)		(0.485)		(0.725)
Gender		−7.256		−10.559**		4.061
		(−1.305)		(−2.170)		(0.522)
Internet		−1.779*		−2.945***		−2.740*
		(−1.967)		(−4.182)		(−1.916)
Constant	38.497***	38.759**	34.107***	81.798***	34.107***	18.879
	(6.851)	(2.087)	(5.146)	(4.958)	(5.146)	(0.368)
Observations	822	822	529	529	529	529
Adjusted R^2	0.878	0.882	0.909	0.926	0.909	0.923
City FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Table 3 shows the baseline results, controlling for regional fixed effects and time fixed effects. The dependent variables are city-level birth rates in columns (1), (2), (5) and (6) while the dependent variables are the forward value of city-level birth rates in columns (3) and (4). The independent variable is city-level total DF index in columns (1), (2) and one year lagged term in column (5) and (6). Detailed definitions of variables are reported in the Appendix. Robust *t*-statistics are reported in parentheses. *, **, and *** denote significance at the 10 %, 5 %, and 1 % levels, respectively.

4. Empirical results

4.1. Baseline regression analysis

Table 3 reports the results of the baseline regression. We estimate the regression between our explanatory variable and dependent variable in column (1) and then we add control variables in column (2). It can be clearly seen that the coefficients of DF are both significantly negative at the 1 % level in columns (1) and (2), which indicates that DF has a negative impact on birth rates. In terms of economic significance, the results indicate that one standard deviation increase in DF development implies a 20.1 % decrease in birth rates.[8] For robustness, we first introduce the forward value of the birth rate and columns (3) and (4) report the results. We also include the lag term of DF and present the result in columns (5) and (6). The coefficients of DF are again significantly negative. In terms of the control variables, and consistent with previous findings (e.g. Yang et al., 2022), we find the high unemployment rate, greater loan burdens and well-developed internet technology have a negative impact on the fertility rates. In addition, the ratio of males (more males in comparison to females) is also negatively related to birth rates. Overall, the baseline results indicates that there is a negative relationship between DF and birth rates, which is consistent with Hypothesis 1b

[8] To test the economic significance, we use the coefficient of DF obtained from regression analysis, the standard deviation of the DF index and mean of birth rates from summary statistics. The calculation is 10.856*0.23/12.406 = 0.201.

4.2. Endogeneity

To avoid the possible reverse causality between DF level and birth rates, we adopt an instrumental variable (IV) approach. Previous literature has shown that communication technology, internet coverage and distance to Hangzhou are good IVs for digital finance (e.g. Mu et al., 2023; Yu et al., 2023). However, evidence also shows that internet and mobile phone use could reduce the demand for children (Dettling, 2017; Billari, 2020), and therefore we choose the distance from the city in our sample to Hangzhou as a potential instrumental variable.[9] However, distance does not change over time, which invalidates the second-stage estimation as an instrumental variable. Therefore, following Zhang et al. (2020), we interact the instrumental variable with the mean of the DF index at the national level (except for the specific city) as our first instrumental variable (*IV-Distance*) with time-varying effects. In addition, considering the strong relation between communication infrastructure and the development of DF, similarly to previous literature such as Chen and Zhang (2021), we introduce our second IV (*IV-Intel)* which is created as the number of Internet users in year *t-1* times the number of fixed-line telephones per 100 people per city in 1984.

Two-stage-least squares regression (2SLS) is employed in the model, and Table 4 shows the results. In panel A, the F-value of *IV-Distance* is 113.125, which is much greater than 10, indicating the instrumental variable is not weak. In column (1), we report the results of the first stage regression. It is clear that the distance instrumental variable is significantly negatively related with DF, implying that the further away from the centre of DF, the lower the level of DF development. This is in line with expectations. The estimation results of the second stage after introducing the instrumental variable, shown in column (2), indicate the coefficient of fitted DF is still significantly negative at the 1 % level, which is consistent with the baseline results.

Panel B of Table 4 reports an F-value of 15.383 for *IV-Intel*, which exceeds the standard threshold of 10, indicating that the instrumental variable is sufficiently strong. Column (1) presents the results of the first-stage regression, showing a significantly positive relationship between the instrumental variable and DF. This suggests that the development of DF is closely associated with the widespread adoption of fixed-line telephone and internet technology, as expected. The second-stage results, displayed in Column (2), indicate that the coefficient of fitted DF remains significantly negative at the 10 % level, consistent with the baseline findings. Both IV-2SLS tests confirm the robustness of the baseline results.

4.3. Robustness tests

To verify the reliability of the baseline results, we also conduct a series of robustness tests, which include adding provincial fixed effects, removing key cities in the sample and using a province-level DF index.

Fertility levels in a city can be influenced by various factors, including socio-economic characteristics, cultural background, and policy orientation at the provincial level. Since the province to which a city belongs is a crucial determinant of fertility, we include province-level fixed effects to control for time-invariant, province-specific factors, enhancing the logical rigor of the analysis. Panel A of Table 5 presents the results, which are consistent with the baseline findings—DF continues to exhibit a negative effect on birth rates.

People who live in key cities with well-developed economies often have access to more advanced finance technology and have more negative fertility intentions. Therefore, it is necessary to test the impact of the development of DF on the birth rates after excluding key cities. Following Shen and Ren (2023), four municipalities directly under the central government, 22 provincial capitals and five cities specifically designated in the state plan[10] are excluded, and the regression results are shown in Table 5 panel B. The results show that the impact of the development of DF on birth rates is still significantly negative after excluding the corresponding key cities, which indicates the baseline findings are robust.

We also introduce a provincial level DF index as an alternative independent variable and rerun the baseline regression. Panel C of Table 5 presents the results. Consistent with baseline findings, the provincial level DF has a negative influence on birth rates.

4.4. Channel tests

In this section, we present the results of our channel tests.

There is an old saying among Chinese, “Yang Er Fang Lao” that means the major goal of parenting is to have someone to look after you in your old age. Traditional fertility decisions are often driven by the need for children to provide support at the old age, especially in economies where formal pension and welfare systems are underdeveloped. However, access to financial services such as insurance, pensions, and investment opportunities could reduce reliance on children for financial security in later life. The advancement of society and the enhancement of social security systems have gradually replaced the traditional role of children in providing old-age support. What was once solely achievable through having children can now be addressed through well-established social security mechanisms (Stevenson et al., 2021). Prior literature suggests that the use of DF boosts financial literacy (Yang et al., 2023) and increases availability of financial services; this in turn influences family planning decisions by mitigating old-age concerns about purchasing life insurance and planning for retirement (Wang et al., 2021; Lusardi and Mitchell, 2017).

Table 6 presents the results in relation to this prediction. First, we divide our sample into high financial institution coverage regions

[9] Hangzhou is located in the eastern region of China and is the capital of the economically developed province of Zhejiang. Hangzhou is also the birthplace and headquarters of Alipay, which is a typical DF company and a leader in DF development in mainland China. Thus, Hangzhou is recognized as the centre of DF technology and has many IT and DF talents.

[10] The city specifically designated in the State Plan include Shenzhen, Dalian, Qingdao, Ningbo and Xiamen.

Table 4
Endogeneity check – 2SLS.

Panel A. Distance to Hangzhou as instrumental variable		
	First Stage	Second Stage
	(1)	(2)
Variables	DF	Birth Rate
DF		−12.465**
		(−2.017)
IV-Distance	−0.010***	
	(−3.911)	
Marketization	0.907***	14.307
	(3.129)	(1.058)
Road	0.006	0.380
	(0.618)	(0.919)
GDP	−0.009**	−0.188
	(−2.143)	(−1.054)
Unemployment	2.314***	−84.180**
	(3.565)	(−2.557)
AQI	0.031	−0.235
	(1.242)	(−0.223)
Education	−0.011	−0.769
	(−0.480)	(−1.041)
Bed	−0.003	−0.083
	(−0.124)	(−0.102)
Elder	0.049	−22.817**
	(0.217)	(−2.124)
Inmarriage	0.026	6.598
	(0.116)	(0.873)
Institution	−0.015	0.006
	(−0.344)	(0.007)
Loan	0.058*	−3.348***
	(1.859)	(−2.696)
Gender	−0.121	−7.956**
	(−1.269)	(−2.112)
Internet	−0.008	−1.735***
	(−0.505)	(−3.099)
Constant	1.816***	46.758***
	(5.891)	(3.674)
Observations	822	822
Adjusted R^2	0.989	0.882
City FE	Yes	Yes
Year FE	Yes	Yes
F-value	113.125	

Panel B. Internet users and fixed-line telephones in 1984 as instrumental variable		
	First Stage	Second Stage
	(1)	(2)
Variables	DF	Birth Rate
DF		−26.766*
		(−1.858)
IV-Intel	0.167**	
	(2.441)	
Marketization	1.671***	38.572
	(6.574)	(1.479)
Road	−0.001	0.343
	(−0.121)	(0.850)
GDP	−0.008*	−0.334
	(−1.717)	(−1.551)
Unemployment	3.021***	−42.418
	(4.237)	(−0.855)
AQI	0.089***	1.158
	(3.549)	(0.636)
Education	−0.049**	−1.453
	(−2.403)	(−1.452)
Bed	−0.009	−0.304
	(−0.356)	(−0.357)
Elder	−0.032	−22.744**
	(−0.129)	(−2.105)
Inmarriage	0.458**	13.412

(*continued on next page*)

Table 4 (*continued*)

Panel B. Internet users and fixed-line telephones in 1984 as instrumental variable		
	First Stage	Second Stage
	(1)	(2)
Variables	DF	Birth Rate
	(2.187)	(1.278)
Institution	0.027	0.521
	(0.713)	(0.497)
Loan	0.075***	−2.291
	(3.017)	(−1.456)
Gender	−0.265***	−12.022**
	(−2.846)	(−2.495)
Internet	0.018	−1.480**
	(1.227)	(−2.484)
Constant	−1.292	119.309***
	(−1.632)	(6.155)
Observations	822	822
Adjusted R^2	0.987	0.871
City FE	Yes	Yes
Year FE	Yes	Yes
F-value	15.383	

This table reports the 2SLS-IV estimation results. Panel A uses the interaction term between the mean of the DF index at the national level (except for the specific city) and the distance to Hangzhou as an instrument variable *Distance* for digital finance level in each city. Panel B uses the interaction term between the number of Internet users in *t-1* and the number of fixed-line telephones per 100 people per city in 1984 as instrumental variable. Detailed definitions of variables are reported in the Appendix. Robust *t*-statistics are reported in parentheses. *, **, and *** denote significance at the 10 %, 5 %, and 1 % levels, respectively.

and low financial institution coverage regions, and we find that the negative impact of DF on birth rates only exists in high coverage regions as shown in Table 6 panel A. Then we classify the sample into two categories: regions with higher insurance purchase and those with lower insurance purchase, based on the sample median in a year. Comparing columns (1) and (2) of panel B of Table 6, it is clear that the negative influence of DF on birth rates is more substantial in regions with higher insurance purchase. This indicates that DF can decrease birth rates because the need to raise children to look after aging parents is reduced with better financial services and higher insurance coverage.

Second, unlike the previous finance literature (e.g. Qu et al., 2023; Yang et al., 2023), which focuses on the possibility of higher incomes and lower financial constraints benefiting from DF as a way of mitigating the cost of childbearing, we focus on the changes in the consumption mindset of newly married or young couples. Psychology literature and business studies both point out the close relationship between consumerism and individualism (Ahuvia, 2002; Lee et al., 2010), while DF makes consumption more convenient, potentially leading to over-consumption and individualism, and thereby reducing birth rates. To test our conjecture, we spilt our sample into two subsamples, which are regions with higher consumer expenditures scaled by GDP per capita and regions with lower consumer expenditures scaled by GDP per capita. We find DF only weakens the regional birth rates in the sample of high consumption regions, as shown in panel A of Table 7.

Opposite to individualism is the family or group oriented social norm. In China, the Han ethnic group constitutes the majority of the population.[11] The other 55 ethnic groups are called minority ethnic groups, as their populations are comparatively smaller. Therefore, the one-child policy was less restrictive among minority ethnic groups in order to support their population levels (Ebenstein, 2010), and minority ethnic groups have the strong social norm of procreation. In response to this social norm, ethnic minority populations pay more attention to the concept of fertility and family legacy (Wan et al., 2021). We divide our sample into ethnic minority provinces and non-ethnic minority provinces.[12] The results in Panel B of Table 7 show that the coefficient of DF is only significantly negative in the sample of non-ethnic minority regions, where people have a stronger sense of individualism and a weaker social norm of fertility.

We further propose DF provides more opportunities for women to enter the labour market and access financial services at a lower cost (Ji et al., 2022). DF leads to higher levels of income and more economic independence for women as found by Han et al. (2023). Childbearing often leads to reduced labour participation or career interruptions, especially for women (Han et al., 2023). This lost potential income can also be compared to disposable income, quantifying how much economic opportunity is traded off for childbearing. In addition, time spent on unpaid domestic labour and childcare can be monetized using the market cost of equivalent services (Folbre, 2006). This conversion reflects the implicit cost of time diverted from income-generating activities. Thus, to further clarify the mechanism of opportunity cost, we divide our sample into high disposable income regions and low disposable income regions based on the sample median of the year. Results have been reported in Table 8 panel A. We can see the negative impact of DF on fertility is larger

[11] According to the latest seventh population census of China, the Han group accounts for 91.11% of the total population. Data is publicly released in *www.gov.cn*.

[12] The ethic minority areas include 5 ethnic minority autonomous regions (Inner Mongolia, Xinjiang, Xizang, Ningxia and Guangxi) and 3 provinces with a high concentration of ethnic minorities (Guizhou, Yunnan and Qinghai). The non-ethnic minority provinces are predominantly inhabited by Han Chinese.

Table 5
Robustness tests.

Panel A. Other fixed effects			
Variables	(1) Birth Rate	(2) Birth Rate$_{t+1}$	(3) Birth Rate
DF	−10.020***	−5.073*	
	(−3.282)	(−1.897)	
L.DF			−9.273***
			(−2.661)
Constant	90.932***	110.073***	9.787
	(3.799)	(4.530)	(0.192)
Observations	822	529	529
Adjusted R^2	0.883	0.926	0.922
Control	Yes	Yes	Yes
City FE	Yes	Yes	Yes
Province-Year FE	Yes	Yes	Yes

Panel B. Eliminating key cities			
Variables	(1) Birth Rate	(2) Birth Rate$_{t+1}$	(3) Birth Rate
DF	−11.375***	−4.689*	
	(−3.302)	(−1.641)	
L.DF			−8.515**
			(−2.385)
Constant	106.896***	93.520***	−16.478
	(3.289)	(3.402)	(−0.306)
Observations	725	465	465
Adjusted R^2	0.882	0.921	0.921
Control	Yes	Yes	Yes
City FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Panel C. Using provincial level total DF index			
Variables	(1) Birth Rate	(2) Birth Rate$_{t+1}$	(3) Birth Rate
$DF_{province}$	−0.068***	−0.030*	
	(−3.149)	(−1.666)	
$L.DF_{province}$			−0.084***
			(−2.667)
Constant	94.422***	109.294***	42.171
	(3.473)	(4.637)	(0.746)
Observations	822	529	529
Adjusted R^2	0.882	0.926	0.925
Control	Yes	Yes	Yes
City FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

This table reports the robustness test results. We add additional province-level fixed effect in Panel A. In Panel B, we remove the key cities in the sample and rerun the baseline regression, while Panel C takes province-level DF index as independent variables. Robust *t*-statistics are reported in parentheses. *, **, and *** denote significance at the 10 %, 5 %, and 1 % levels, respectively.

in high disposable income regions, where the opportunity cost of childbirth is higher for women.

In addition, in regions where there is a higher proportion of females, women are likely to have a stronger voice (e.g. Goodkind, 2011). Bulte et al. (2015) find that a higher female ratio increases females' bargaining power with respect to household purchases, education, labour market engagement and fertility. Women bear most of the cost of having children in the family, but in regions with a high female ratio, women may have stronger voices regarding child-raising. We compare the impact of DF on birth rates in regions with different gender ratios. The results in panel B of Table 8 indicate that DF has a negative impact on birth rates in cities with a higher female ratio, suggesting that in those cities women have more independence with respect to fertility decisions.

In all, the channel test results explain the potential reasons why DF affects birth rates. We create a conduction diagram to visually represent the relationship between these channel factors. The graph is shown in Fig. 4.

4.5. Sub-categories of the DF index

Given DF development is a non-stoppable trend, will further development of DF continue to impact the birth rate in the future? We try to answer this question by investigating sub-categories of the DF index. According to previous literature (e.g. Li et al., 2020; Mu et al., 2023), DF is a multi-dimensional concept, and therefore our paper not only examines the impact of the total index of DF on

Table 6
Channel tests - Investment opportunities.

Panel A. Financial institution coverage (FIC)

	High	Low
	(1)	(2)
Variables	Birth Rate	Birth Rate
DF	−7.900***	3.665
	(−2.900)	(0.513)
Constant	−21.764	24.680
	(−0.447)	(0.650)
Observations	428	394
Adjusted R^2	0.916	0.883
Control	Yes	Yes
City FE	Yes	Yes
Year FE	Yes	Yes

Panel B. Commercial insurance purchase (CIP)

	High	Low
	(1)	(2)
Variables	Birth Rate	Birth Rate
DF	−6.708*	−1.126
	(−1.890)	(−0.306)
Constant	80.418***	11.855
	(2.663)	(0.417)
Observations	434	388
Adjusted R^2	0.881	0.925
Control	Yes	Yes
City FE	Yes	Yes
Year FE	Yes	Yes

This table reports the test results regarding the channel of investment and insurance. The channel variables are *FIC* and *CIP* separately. *FIC* refers to the average number of financial institution outlets serviced per 10,000 population of a province, while *CIP* refers to the average commercial insurance purchase per person of a province. Detailed definitions of variables are reported in the Appendix. Robust *t*-statistics are reported in parentheses. *, **, and *** denote significance at the 10 %, 5 %, and 1 % levels, respectively.

fertility rates but also uses the sub-category indices in the regression analysis. Table 9 presents the results for the impact of DF on birth rates using the different dimensions of the index. We find all the sub-indices including coverage breadth, depth of use and level of digitization have negative impacts on fertility. However, in contrast with the other two categories, the negative relationship is only significant at the 1 % level for breadth of coverage. The results from Table 9 indicate that as DF technology continues to move from coverage to depth and digitization, its negative effect on the birth rate will reduce.

The possible explanation is that DF, taking advantage of its inclusiveness, makes financial services more accessible to more households and reduces the cost of financial services (Ji et al., 2021). Financial inclusion refers to the accessibility and availability of formal financial services to all members of society, ensuring that individuals and businesses can utilize affordable financial products that meet their needs responsibly and sustainably (Mader, 2018). According to Mhlanga (2020), in the context of the Fourth Industrial Revolution, the current digital financial inclusion emphasizes financial inclusion initiatives for vulnerable populations — such as the poor, women, the elderly, and disabled individuals—who are more susceptible to financial exclusion and economic shocks. This convenience and cost reduction make it easier for households to participate in financial markets and invest and purchase financial products such as insurance, which in turn reduces the need to rely on future generations for old age financial security. However, depth and digitalization focus more on the sophistication and efficiency of financial services and technological advancement (Li et al., 2020). Therefore, the negative impact of depth and digitalization on birth rate is limited.

4.6. *Moderating effects of government policies*

Because child-raising is treated as a type of investment, the expense to become responsible parents, such as the increasing costs of children education and rising living expense, increases with the development of the economy (Preston, 1986; Lin and Kamo, 2015). Given that the development of DF is an inevitable trend going forward, we investigate whether government policies on providing more support for raising children and protecting the social norm of fertility may weaken or moderate the negative effect of DF on birth rates.

A large number of sociological surveys and studies have shown that contemporary Chinese couples bear enormous pressures when faced with child-raising (e.g. Qian and Jin, 2018). These pressures include covering children's future education and health expenses. The current distribution imbalance of education and medical resources in China has exacerbated their worries about becoming parents (Zhang et al., 2015). Meanwhile, high property prices have put pressure on many young couples to take out mortgages (Gao et al., 2022). These issues, on the one hand, require them to spend more time on work to ensure a stable income, thus reducing the time for

Table 7
Channel tests - Individualism and social norm.

Panel A. Consumption		
	High	Low
	(1)	(2)
Variables	Birth Rate	Birth Rate
DF	−11.696**	−6.433
	(−2.577)	(−1.077)
Constant	155.240***	64.793*
	(3.491)	(1.682)
Observations	412	410
Adjusted R^2	0.901	0.875
Control	Yes	Yes
City FE	Yes	Yes
Year FE	Yes	Yes

Panel B. Ethnic groups		
	Ethnic minority areas	Non- ethnic minority areas
	(1)	(2)
Variables	Birth Rate	Birth Rate
DF	−2.807	−11.914***
	(−0.307)	(−3.141)
Constant	−2.509	73.293**
	(−0.019)	(2.512)
Observations	136	686
Adjusted R^2	0.877	0.889
Control	Yes	Yes
City FE	Yes	Yes
Year FE	Yes	Yes

Table 7 reports the channel test of individualism and social norms. We use the average total expenditures made by consumers per person scaled by GDP per capita in the region (*Consumption*), and ethnic minority areas vs. non-ethnic minority areas (*Ethnic*) respectively. Detailed definitions of variables are reported in the Appendix. Robust *t*-statistics are reported in parentheses. *, **, and *** denote significance at the 10 %, 5 %, and 1 % levels, respectively.

family life. On the other hand, mortgages constrain their financial freedom and reduces the possibility of investing in their children. In addition, technological development stimulates the formation of individualism and challenges the belief in fertility and family (He et al., 2019; Wan et al., 2021). However, religious beliefs emphasize family ties and family lines (Wan et al., 2021).

Based on the above discussion, in Table 10 we report the effects of DF on birth rates with *Teacher, Doctor, House* and *Religious site* selected as the moderating variables. *Teacher* is the average number of teachers per 100 students at the compulsory education stage in a province. *Doctor* measures the number of certificated physicians in a province. *House* is measured as the natural logarithm of average sales price of residential property in the province. Last, as evidence of the local level of religious protection, *Religious site* is measured as the number of religious sites per 10,000 square kilometers in a province.[13] The results show that the negative relationship between DF and the birth rate is moderated when regions have richer education resources, more certificated doctors, lower house price pressure and more religious sites.

5. Conclusion, policy implications and future research

In recent years, there has been rapid development of DF based on digital technologies. Combining the city level data of birth rates and the DF index, this paper performs empirical analyses on the impacts of DF on fertility and explores the channels and moderators of this relationship. We find that DF has a negative effect on birth rates and this finding is verified by the robustness and endogeneity tests. Second, we find that DF affects birth rates via the channels of increasing investment opportunities, increasing consumption and individualism, and increases women's economic independence and opportunity costs of fertility. Furthermore, by using the sub-categories of the DF index, we find that as DF technology continues to improve from coverage to depth and digitization, its negative effect on the birth rate will reduce. Last, we find the negative effect of DF on birth rates can be moderated by government policies in enhancing people's fertility willingness.

Based on the above findings, our study has the following potential policy implications. First, previous evidence shows that DF improves financial services and products, increases consumption, and increases women's economic independence, while these positive direct economic impacts could potentially negatively impact social behaviours such as birth rates, and therefore harm economic

[13] Due to the data availability in CSMAR, we use the number of religious sites in 2018 to proxy the number in 2017.

Table 8
Channel tests - Opportunity cost for women and women's voice.

Panel A. Disposable Income		
	High	Low
	(1)	(2)
Variables	Birth Rate	Birth Rate
DF	−6.757**	−9.881
	(−2.052)	(−1.252)
Constant	122.052***	106.365*
	(3.138)	(2.004)
Observations	425	397
Adjusted R^2	0.906	0.871
Control	Yes	Yes
City FE	Yes	Yes
Year FE	Yes	Yes

Panel B. Gender (Male/Female) ratio		
	High	Low
	(1)	(2)
Variables	Birth Rate	Birth Rate
DF	1.796	−10.437**
	(0.446)	(−2.230)
Constant	12.765	109.508**
	(0.433)	(2.361)
Observations	425	397
Adjusted R^2	0.894	0.875
Control	Yes	Yes
City FE	Yes	Yes
Year FE	Yes	Yes

Table 8 reports the channel test of opportunity cost of fertility for women. We use the regional disposable income and the male/female gender ratio (*Gender*) in the region divide all cities into high and low groups according to the median value in a year, respectively. Detailed definitions of variables are reported in the Appendix. Robust *t*-statistics are reported in parentheses. *, **, and *** denote significance at the 10 %, 5 %, and 1 % levels, respectively.

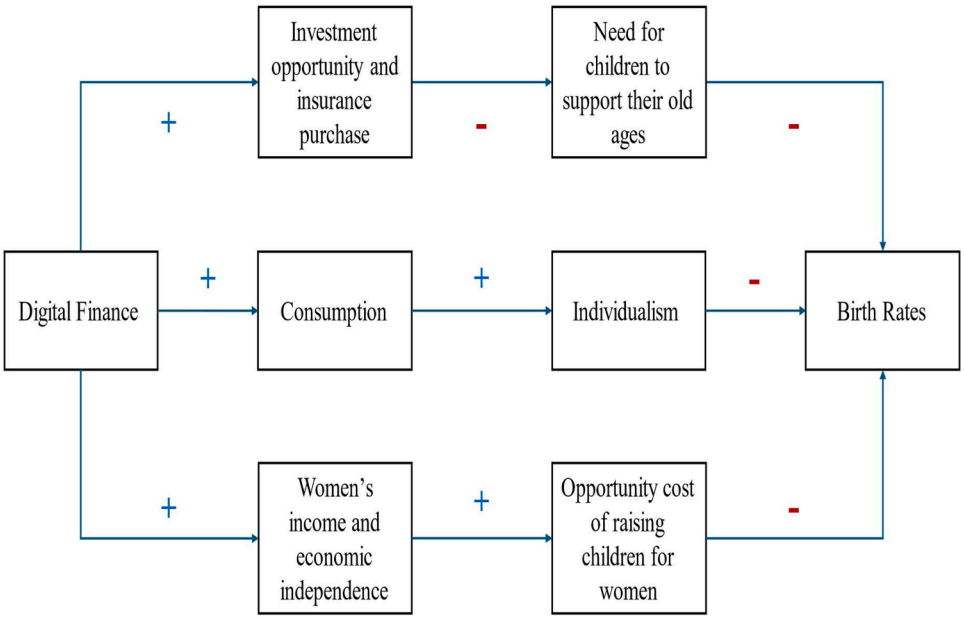

Fig. 4. The channels between DF and birth rates.

Table 9
Alternative proxies for digital finance.

Variables	(1) Birth Rate	(2) Birth Rate$_{t+1}$	(3) Birth Rate	(4) Birth Rate$_{t+1}$	(5) Birth Rate	(6) Birth Rate$_{t+1}$
Coverage	−0.139***	−0.149***				
	(−3.321)	(−2.721)				
Depth			−0.031*	−0.002		
			(−1.774)	(−0.127)		
Digit					−0.017**	−0.008
					(−2.166)	(−0.883)
Marketization	1.483	−33.222***	1.171	−40.116***	−0.768	−34.093
	(0.134)	(−2.639)	(0.116)	(−2.895)	(−0.068)	(−1.595)
Road	0.527	−0.668	0.345	−0.834	0.445	−0.805
	(0.758)	(−1.288)	(0.684)	(−1.577)	(0.627)	(−1.018)
GDP	0.035	−0.016	−0.134	−0.103	−0.134	−0.125
	(0.120)	(−0.105)	(−0.720)	(−0.661)	(−0.466)	(−0.647)
Unemployment	−88.500**	−260.616***	−105.418***	−305.417***	−119.697***	−296.772***
	(−2.047)	(−5.600)	(−3.290)	(−6.445)	(−2.862)	(−4.888)
AQI	−0.741	−1.674	−1.014	−1.881	−1.212	−2.008
	(−0.467)	(−1.267)	(−0.849)	(−1.392)	(−0.751)	(−0.847)
Education	−0.266	0.982	−0.424	1.094	−0.499	0.787
	(−0.247)	(1.113)	(−0.482)	(1.214)	(−0.463)	(0.621)
Bed	0.078	0.461	−0.051	0.037	−0.001	0.072
	(0.056)	(0.404)	(−0.052)	(0.033)	(−0.000)	(0.057)
Elder	−26.500	−23.739***	−23.102**	−22.239**	−21.553	−22.749
	(−1.421)	(−2.671)	(−2.464)	(−2.469)	(−1.137)	(−1.500)
Inmarriage	1.939	−11.999	2.883	−14.731	3.354	−14.122
	(0.167)	(−1.121)	(0.305)	(−1.360)	(0.290)	(−1.007)
Institution	−0.970	−2.040	−0.198	−2.134	−0.169	−1.904
	(−0.721)	(−1.584)	(−0.139)	(−1.593)	(−0.122)	(−0.834)
Loan	−3.433**	1.100	−4.325***	−0.156	−4.055**	0.122
	(−2.003)	(0.772)	(−3.272)	(−0.112)	(−2.154)	(0.071)
Gender	−7.013	−10.041**	−5.452	−8.868*	−5.279	−9.726
	(−1.287)	(−2.106)	(−1.352)	(−1.820)	(−0.954)	(−1.249)
Internet	−1.362	−2.594***	−1.851***	−3.163***	−2.088**	−3.145***
	(−1.544)	(−3.593)	(−2.762)	(−4.425)	(−2.307)	(−2.984)
Constant	104.810***	118.991***	100.257***	116.796***	100.346***	113.877***
	(4.039)	(5.207)	(4.804)	(4.937)	(3.738)	(3.730)
Observations	822	529	822	529	822	529
Adjusted R^2	0.882	0.927	0.879	0.925	0.880	0.925
City FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Table 9 reports the regression results after we introduce sub-categories of the DF index. The three dimensions of DF index in the ranking system are coverage breadth (*Coverage*), index of use depth (*Depth*) and degree of digitization (*Digit*). Robust *t*-statistics are reported in parentheses. *, **, and *** denote significance at the 10 %, 5 %, and 1 % levels, respectively.

development from a long run perspective. Policy makers need to be aware of the potential challenges related to fast development of DF, and understanding its impact on birth rates is both academically valuable and policy relevant. Second, our study highlights the importance of government medical and education support, freedom of religious belief and a shifting policy focus in DF development from coverage to depth and digitization in mitigating the negative impact of DF on birth rates. These findings have impactful policy implications with respect to fertility encouragement and further DF development.

Looking ahead, there are several promising avenues for future research. First, future studies could further examine how the evolution of DF from basic coverage to deeper integration and advanced digitization can mitigate its negative impacts on declining birth rates and other potential social outcomes. A more nuanced understanding of how different levels of DF interact with household decision-making and life planning is crucial for designing inclusive financial systems that support long term social development goals. Second, we suggest further exploration of the cross-national implications of DF for women's economic empowerment and shifting family structures. Building on our findings, comparative studies across different cultural and institutional contexts can offer valuable insights into whether these patterns are globally consistent or shaped by local norms and policies. Such research can inform the development of more balanced financial and social policies that promote both economic inclusion and demographic sustainability.

CRediT authorship contribution statement

Junshi Chen: Writing – review & editing, Writing – original draft, Methodology, Data curation. **Jing Chi:** Writing – review & editing, Supervision, Project administration, Conceptualization. **David Smith:** Writing – review & editing, Supervision, Conceptualization. **Mui Kuen Yuen:** Writing – review & editing, Supervision, Conceptualization.

Table 10
Moderating effects–Government policies.

Variables	(1) Birth Rate	(2) Birth Rate	(3) Birth Rate	(4) Birth Rate
DF*Teacher	**7.186*** **			
	(5.625)			
DF	−53.419***			
	(−6.293)			
Teacher	−15.222***			
	(−5.497)			
DF*Doctor		**9.455** **		
		(2.374)		
DF		−42.086***		
		(−2.797)		
Doctor		−28.978***		
		(−3.175)		
DF* 1/House			**99.869**	
			(0.618)	
DF			−20.185	
			(−1.176)	
1/House			−339.540	
			(−0.856)	
DF*Religious site				**0.797**
				(1.124)
DF				−14.664***
				(−2.959)
Religious site				−1.530
				(−1.017)
Constant	126.967***	179.186***	139.343**	111.673***
	(4.797)	(5.246)	(2.435)	(3.536)
Observations	822	822	822	822
Adjusted R^2	0.896	0.885	0.882	0.882
Control	Yes	Yes	Yes	Yes
City FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Table 10 reports the results of moderating effects. The moderating variables are *Teacher, Doctor, House* and *Religious site* accordingly. *Teacher* refers to average number of teachers per 100 students at the compulsory education stage (primary school and secondary school). *Doctor* is measured by the natural logarithm of the number of practicing physicians per 10,000 population. *House* is the natural logarithm of average sales price of residential property (Chinese RMB per square metre) and *Religious site* is calculated as the natural logarithm of the number of religious sites (Buddhist temples and Taoist monasteries) per 10,000 square kilometres. Detailed definitions of variables are reported in the Appendix. Robust *t*-statistics are reported in parentheses. *, **, and *** denote significance at the 10 %, 5 %, and 1 % levels, respectively.

Declaration of competing interest

No potential conflict of interest was reported by the authors.

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Appendix. Variable definition

Variables	Definitions
Birth rate	Births per year /Average population per year in the city *1000 ‰
DF	The index of Digital Finance of the city in the year divided by 100
Marketization	1- (the number of public-sector and collective employees as a proportion of the total number of employees), following Yang et al. (2022)
Road	The natural logarithm of road surface area per capita (m^2) in the city
GDP	The natural logarithm of GDP per capita of the city
Unemployment	The unemployment rate of the province
AQI	Air quality index, which is the natural logarithm of the average daily AQI (the concentration level of six atmospheric pollutants, namely, SO_2, NO_2, PM10, PM2.5, CO, and O_3) for a given year and city. The higher the AQI, the heavier the air pollution the city has.
Education	The natural logarithm of population with tertiary education and above (based on data from the 1 ‰ population sample survey conducted by the NBSC)
Bed	The natural logarithm of hospital beds per 10,000 population in the city
Elder	Ratio of the number of people 65+ to the number of people of working age (16–59) in the province

(*continued on next page*)

(*continued*)

Variables	Definitions
Unmarried	Ratio of unmarried persons to the number of persons aged 15 years and over in the province (based on 1 ‰ population sample survey conducted by the NBSC)
Institution	Financial institution coverage, measured as the average number of financial institution outlets serviced per 10,000 population of the province
Loan	The natural logarithm of the loan balance per capita of the province
Gender	Ratio of male to female population in the province (based on data from the 1 ‰ population sample survey conducted by the NBSC)
Internet	The natural logarithm of the total internet usage per capita of the province
IV-Distance	Instrumental variable, measured as the interaction term between the mean of the DF index at the national level (except for the specific city) and the distance to Hangzhou
IV-Intel	Instrumental variable, measured as the interaction term between the number of Internet users in year *t-1* at the national level and the number of fixed-line telephones per 100 people per city in 1984
CIP	Commercial insurance purchase, measured as the natural logarithm of commercial insurance purchased per capita of the province
Consumption	The average total expenditures made by consumers per person in the province scaled by GDP per capita
Ethnic	Dummy variable equals to one if the province is an autonomous region or concentration of ethnic minorities, and 0 otherwise
Disposable income	The natural logarithm of disposable income per person of the province
Teacher	The average number of teachers per 100 students at the compulsory education stage (primary school and secondary school) in a province
Doctor	The natural logarithm of the number of practicing physicians per 10,000 population in a province
House	The natural logarithm of average sales price of residential property (Chinese RMB per square metre) in a province
Religious site	The natural logarithm of the number of religious sites (Buddhist temples and Taoist monasteries) per 10,000 square kilometers in a province

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