



Development Model of Factors Influencing the Adoption of Online Education Platforms for Promoting Educational Equity in Chinese Higher Education

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ABSTRACT

In the era of digital education, fostering online education for sustainable development emerges as a critical challenge, particularly in bridging the digital divide that hinders equitable access to digital education technologies. This study aims to uncover the impact of the digital divide on higher education students' engagement with online education platforms aimed at education equality. Additionally, it seeks to assess the mediating roles of equity in resource allocation and educational process fairness. Leveraging online surveys, data were amassed from students across Tsinghua University, Peking University, Fudan University, Nanjing University, and SouthWest JiaoTong University, encompassing a diverse cohort of 449 individuals with varying degrees and experiences in utilizing online education platforms for learning about sustainable development. Employing structural equation modeling, the analysis revealed that the digital divide adversely impacts both the equity of resource distribution and the fairness of the educational process, thereby deterring the adoption of online education platforms for education equality. Conversely, equitable resource distribution and a fair educational process were found to positively influence platform adoption. Importantly, equity in resource distribution and educational process fairness were identified as critical mediators between the digital divide and the utilization of online education platforms for education equality. These findings underscore the necessity of enhancing equity in resource distribution and the educational process to mitigate the digital divide's negative effects, thereby fostering greater engagement with online education platforms among higher education students for sustainable development.

Keywords: online education, sustainable development, SDG4, equality, digital divide, educational resources, educational process

Introduction

In the contemporary landscape of education, the advent of digital technologies has heralded a new era of learning opportunities, offering unprecedented access to information and educational resources (Jiang et al., 2022). This digital evolution plays a pivotal role in advancing sustainable development goals (SDGs), particularly SDG4, which aims to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all (Jiang & Pu, 2022). However, the promise of digital education is marred by the persistence of the digital divide—a multifaceted phenomenon characterized by unequal access to information and communication technologies (ICTs), as well as disparities in digital skills and literacy among different populations (Gadi, 2021). The digital divide not only exacerbates existing inequalities but also poses a significant barrier to the realization of sustainable development through education (Shaturae, 2021).

Online education platform for sustainable development is a digital infrastructure designed to facilitate the delivery, management, and engagement of educational content and experiences focused on sustainable development goals (SDGs) (Pizzi, Caputo, Corvino, & Venturelli, 2020). It encompasses a broad spectrum of digital tools and resources, including but not limited to, learning management systems (LMS), open educational resources (OER), interactive simulations, and collaborative forums (HerreraPavo, 2021). These platforms leverage information and communication technologies (ICTs) to provide accessible, flexible, and inclusive educational opportunities that cater to a diverse range of learners, irrespective of their geographical location or socio-economic status (Avvisati, 2020). Within the context of sustainable development, online education platforms are instrumental in disseminating knowledge and fostering competencies that empower individuals to contribute to the attainment of SDGs (Mpofu, 2022). This includes promoting understanding of sustainability principles, environmental stewardship, social equity, and economic viability, thereby equipping learners with the skills and attitudes necessary for enacting positive change. The digital nature of these platforms enables the incorporation of multidisciplinary approaches and perspectives, facilitating a holistic and integrated learning experience that is essential for addressing the complex challenges of sustainable development (Ruggerio, 2021). Moreover, online education platforms for sustainable development are characterized by their ability to offer personalized learning paths, real-time feedback, and peer-to-peer interaction, enhancing learner engagement and motivation. They also serve as vital tools for continuous professional development, allowing individuals to update their knowledge and skills in response to evolving sustainability issues and practices (Laufs & Waseem, 2020). In sum, an online education platform for sustainable development represents a critical mechanism for expanding educational access, enhancing quality of learning, and fostering global citizenship and sustainability awareness. Through leveraging digital innovations, these platforms play a pivotal role in advancing education for sustainable development, thereby contributing to the global agenda of achieving a more sustainable and equitable world.

The significance and future orientation of digital education, spotlighting the digital divide in China's higher education as a pivotal concern (Blankstein, Frederick, & Wolff-Eisenberg, 2020). This divide encompasses three primary dimensions: the digital usage divide among learners, the digital design divide among educators, and the digital access divide within the educational environment (Kye, Han, Kim, Park, & Jo, 2021). As technological advancements continue to reshape the external landscape of education, they concurrently alter the fundamental dynamics within the educational sphere (Sidorova, Tarubarov, Okruzhko, Vasiliev, & Pelevin, 2020). The evolution from electronic learning resources to multimedia and digital platforms has expedited the development of a new educational resource distribution system (Brannen & Wilson, 2023). This transformation provides essential tools for innovative teaching and learning methodologies, thereby encouraging the advancement of higher education through the refinement of educational strategies, institutional models, management systems, and support mechanisms (LaMoia & Shulman, 2021).

However, the digital transformation journey in higher education encounters substantial challenges, especially with the rapid progression of artificial intelligence and online education platforms (Chen et al., 2020). These technological advancements pose intricate technical challenges to leveraging online education for promoting educational equity (Miller, Liu, & Ball, 2020). Digital technology is profoundly redefining online education, manifesting systematic shifts across various aspects including the learning environment, educational resources, the caliber of teachers and students, pedagogical methods, and evaluative measures (Y. Ng, 2020). Online education harbors immense potential to foster educational equality by transcending geographic and socio-economic disparities, thereby democratizing access to high-quality educational resources (Glewwe, Siameh, Sun, & Wisniewski, 2021). Irrespective of their location, students have the opportunity to access knowledge via the internet (Xie, Yu, Zeng, Yang, & Liu, 2020). Online platforms offer personalized learning trajectories and resources tailored to individual interests, learning styles, and progress, addressing the diverse needs of students and promoting educational equity (Aguliera & Nightengale-Lee, 2020). Moreover, online education affords learners the flexibility to study at their own pace and schedule, accommodating both full-time professionals and students with rigorous academic commitments (L.-K. Ng & Lo, 2022).

Despite its capacity to eliminate geographical barriers, the digital divide remains a persistent challenge. The disparity in stable internet connectivity, availability of digital devices, and digital literacy levels restricts equal access to learning opportunities (Jæger & Blaabæk, 2020). The prerequisite for digital technology in online education means that individuals without sufficient access or digital competencies may find themselves marginalized from digital learning environments (Anthonysamy, Koo, & Hew, 2020). While online education enhances the accessibility of educational resources, socioeconomic, gender, and other forms of inequality continue to pose barriers. The lack of necessary equipment or conducive study environments remains a significant obstacle for some, highlighting the nuanced complexities of achieving educational equality in the digital age.

The digital divide in Chinese higher education institutions is obvious. The urgency to address divide has become more pronounced in the context of higher education, where online platforms have become integral to learning and research, especially in promoting concepts of sustainable development (Ruggerio, 2021).

This research aims (1) to explore how the digital divide affects higher education students' adoption online education platforms for education equality. (2) to examine the mediating roles of fair resource allocation and fairness in the educational process.

Literature review

The digital divide, defined as the gap between individuals who have access to modern information and communication technology (ICT) and those who do not, can lead to unequal opportunities in accessing digital resources (Hehir, Zeller, Luckhurst, & Chandler, 2021). This divide can affect various sectors, including healthcare, education, and employment, where digital access determines the availability of resources (Di Giorgio et al., 2020). For instance, during the COVID-19 pandemic, the digital divide highlighted disparities in access to information, remote work capabilities, and online education.

Norris (2001) suggests that the digital divide reflects broader socio-economic inequalities, affecting resource allocation across communities. The World Bank reports emphasize that bridging the digital divide could lead to more equitable development outcomes, particularly in low- and middle-income countries. Digital divide (Lythreathis, Singh, & El-Kassar, 2022) exacerbates existing inequalities in resource distribution, limiting the access of underprivileged groups to vital services and opportunities.

Empirical research could investigate correlations between ICT access levels and metrics of resource allocation fairness (Zhou & Zhang, 2021) within different sectors. Hence, this study propose:

H1: Digital divide negatively affects the fair resource allocation.

The adoption of online education platforms has been heralded as a means to democratize access to education (Barger, 2020). However, disparities in digital access limit the potential for these platforms to achieve educational equality (Komljenovic, 2021). Factors such as lack of internet access, digital literacy, and affordable digital devices hinder the widespread adoption of online education, particularly among marginalized communities. Hargittai (2002) and DiMaggio et al. (2001) proposed that digital literacy and access significantly influence the ability to benefit from online educational resources. The UNESCO 2020 report on global education inequality highlights the digital divide as a critical barrier to achieving inclusive education for all. The digital divide undermines (Sala, Gaia, & Cerati, 2022) the potential of online education platforms to provide equitable educational opportunities. Research could explore how differences in digital access among socio-economic and geographical groups impact the adoption rates and outcomes of online education (Martin, Sun, & Westine, 2020). This study proposes:

H2: Digital divide negatively affects the adoption of online education platforms for education equality

Beyond access to technology, the digital divide also encompasses disparities in the ability to effectively utilize digital tools for learning (Hillmayr, Zierwald, Reinhold, Hofer, & Reiss, 2020). This extends to the quality of digital education received, with students in well-resourced areas benefiting from higher-quality content, more interactive learning experiences, and better support from educators trained in digital pedagogy (Pongsakdi, Kortelainen, & Veermans, 2021). Selwyn (2004) discusses the qualitative aspects of the digital divide, emphasizing that mere access to technology does not ensure (Torous, Myrick, Rauseo-Ricupero, & Firth, 2020) effective learning. The fairness in the education process is compromised by not only who can access digital education but also by the quality and relevance of the digital education provided (Decuyper, Grimaldi, & Landri, 2021). The impact of the digital divide on the equity of educational processes, including the quality of education and the support structures available to students (Barrot, Llenares, & Del Rosario, 2021). Hence, this study assumes.

H3: Digital divide negatively affects the fairness in the education process.

Equitable resource allocation ensures that educational institutions and learners have access to the necessary tools and infrastructure to engage with online education platforms effectively (Liu, Lomovtseva, & Korobeynikova, 2020). This includes not only hardware and software but also support services and training for educators and students (Luiz, Lindell, & Ekuni, 2020). When resources are distributed fairly, schools and learners in underprivileged areas are better equipped to participate in digital learning, thereby narrowing the digital divide and fostering a more inclusive educational environment (Nilholm, 2021).

The studies about equitable resource allocation posits that addressing disparities in educational resources can lead to more uniform adoption rates of technological innovations across different socioeconomic groups (Levin, 2012). Research by Zhao and Frank (2003) supports the idea that schools with adequate resources are more likely to adopt and effectively integrate technology in teaching and learning processes.

When educational resources, including technology, are allocated equitably across schools and communities, there is a higher likelihood of widespread adoption of online education platforms (Chen et al., 2020). This can be investigated through comparative studies examining the correlation between measures of resource allocation fairness and the rate of online education platform adoption in various educational settings (Säljö, 2023). Hence, this study assumes:

H4: Fair Resource Allocation Positively Affects the Adoption of Online Education Platforms for Education Equality

Fairness in the education process encompasses a broad range of practices, from inclusive pedagogy to equitable access to learning materials and support. In the context of online education, this could mean providing personalized learning experiences, ensuring content is accessible to students with disabilities, and offering support for students who are struggling (Febriyanti, Simanjuntak, & Sutrisno, 2022). When students perceive the education process as fair and inclusive, they are more likely to engage with and benefit from online education platforms. According to the theory of educational equality, perceptions of fairness in educational processes are crucial for student motivation and engagement (Deci & Ryan, 1985). The equitable practices in

education, such as personalized learning and support for diverse learning needs, enhance students' willingness to engage with educational technology (Baker et al., 2008). The fairness of the education process, characterized by equitable treatment and opportunities for all students, encourages the adoption and effective use of online education platforms (Chirikov, Semenova, Maloshonok, Bettinger, & Kizilcec, 2020). Thus, this study posits: H5: Fairness in the Education Process Positively Affects the Adoption of Online Education Platforms for Education Equality

The digital divide represents disparities in access to and use of information and communication technologies (ICTs), which can impede the adoption of online education platforms (Chen et al., 2020). However, equitable distribution of resources (such as internet access, digital devices, and supportive educational materials) can mitigate these barriers, facilitating greater adoption and use of online education platforms across different socio-economic groups (Ferguson et al., 2020).

The resource allocation plays a critical role in bridging the gap created by the digital divide (Zhao & Frank, 2003; Warschauer, 2004). Equitable resource allocation can provide the necessary infrastructure and support for all learners, regardless of their background, to access and benefit from online education (Paudel, 2021).

The fairness of the education process, which includes practices such as inclusive pedagogy, equitable access to learning opportunities, and support for diverse learners, may lessen the negative impact of the digital divide on the adoption of online education (Mittal, Mantri, Tandon, & Dwivedi, 2022). Educational equity theory emphasizes that equitable educational practices contribute to positive educational outcomes, even in the face of structural disadvantages like the digital divide (Deci & Ryan, 1985; Baker et al., 2008). Fair educational processes ensure that all students feel valued and supported, encouraging engagement with digital learning tools despite the initial barriers posed by the digital divide. Hence, this research develops:

H6. Fair resource allocation mediates the relationship between the digital divide and adoption online education platform for education equality.

H7. Fairness in the education process mediates the relationship between the digital divide and adoption online education platform for education equality.

3. Method

3.1 Data collection

Using an online questionnaire, this study surveyed students from Tsinghua University, Peking University, Fudan University, Nanjing University, and SouthWest JiaoTong University through purposive sampling. A total of 449 valid samples were collected, all of whom had online Participants who have experience using educational platforms and have a certain understanding of educational equity.

Table 1 outlines the demographic and background information of 449 participants involved in a study examining the usage and perceptions of online education platforms. The gender distribution with 224 males (49.9%) and 225 females (50.1%), Age-wise, participants are predominantly young adults, with a substantial number below 25 years (71.3%), divided into three age groups: less than 20 years (25.6%), 20-22 years (20.3%), and 22-25 years (25.4%), along with those older than 25 years making up 28.7% of the sample. Regarding experience with online education platforms, the participants' experience levels vary, providing a broad perspective on user engagement. A notable proportion has less than 1 year of experience (26.1%), followed by those with 1-2 years (28.7%), 2-3 years (21.8%), and more than 3 years (23.4%), illustrating a diverse range of familiarity and expertise with online learning environments. Participants have reported experience with a variety of platforms, including New Oriental (10.5%), Gaotu (9.4%), Offen (10.2%), Huatu Online (10.5%), Huijiang (8.0%), Fenbi (10.0%), Youdao Quality Course (12.7%), NetEase Cloud Classroom (9.8%), Tencent Classroom (10.2%), and Open University of China (8.7%). The sample consists of individuals from both urban (52.3%) and rural areas (47.7%). Affiliations with prestigious universities such as Tsinghua University (24.5%), Peking University (27.6%), Fudan University (22.0%), Nanjin University (25.8%), and SouthWest JiaoTong University (24.5%) are noted, suggesting that the majority of participants are likely to have a strong academic background. The family income distribution shows a relatively even spread across different income brackets, with the lowest (<100,000 ¥) and the highest (>300,000 ¥) income groups each constituting less than 20% of the sample. This variation in economic backgrounds can provide insights into the affordability and accessibility of online education platforms across different socioeconomic statuses. The participants' education levels are diverse, with 37.2% holding a Bachelor's degree, 34.1% with a Master's, and 28.7% with a Doctorate. This diversity indicates a sample with a high level of education, which may influence their engagement with and perceptions of online education platforms.

Table 1. Information of the participants

Information		Frequency	Percent (%)
Gender	Male	224	49.9
	Female	225	50.1
Age	<20	115	25.6
	20-22	91	20.3
	22-25	114	25.4
	>25	129	28.7
Experience in using an online education platform	Less than 1 year	117	26.1
	1-2 Years	129	28.7
	2-3 Years	98	21.8
Platforms experience	More than 3 years	105	23.4
	New Oriental	47	10.5
	Gaotu	42	9.4
	Offcn	46	10.2
	Huatu Online	47	10.5
	Hujiang	36	8.0
	Fenbi	45	10.0
	Youdao Quality Course	57	12.7
	NetEase Cloud Classroom	44	9.8
	Tencent Classroom	46	10.2
Area	Open University of China	39	8.7
	Urban area	235	52.3
	Rural area	214	47.7
Affiliation	Tsinghua University	110	24.5
	Peking University	124	27.6
	Fudan University	99	22.0
	Nanjing university	116	25.8
	SouthWest JiaoTong University	110	24.5
Family income/ year	<100000 ¥	88	19.6
	100000 ¥ -200000 ¥	87	19.4
	200000 ¥ -250000 ¥	99	22.0
	250000 ¥ -300000 ¥	89	19.8
	>300000 ¥	86	19.2
Education level	Bachelor	167	37.2
	Master	153	34.1
	Doctor	129	28.7

3.2 Survey instrument

The measurement of the digital divide in this study is inspired by the framework of Gupta and Yadav (2022), encapsulating five key dimensions and 7 items: access, autonomy, skills, social support, and purpose. These dimensions are operationalized through a seven-item scale, where participants rate their agreement from 1 (Strongly Disagree) to 7 (Strongly Agree). Access is measured by reliable availability of a computer and internet. Autonomy assesses unrestricted internet usage. Skills are differentiated into basic and advanced digital tasks. Social Support is gauged by the availability of help with digital technologies. Purpose is captured through the use of the internet for information seeking and communication.

The fair resource allocation in organizations is measured using an adaptation of the organizational justice scale by (Cugueró-Escofet et al., 2019), focusing on perceptions of distributive, procedural, and interactional justice, along with an overall fairness assessment. This adaptation comprises four items, each rated on a 1-7 scale (Strongly Disagree to Strongly Agree). Distributive Justice assesses the perceived fairness of resource distribution outcomes. Procedural Justice evaluates the perceived fairness of the processes leading to those outcomes. Interactional Justice measures the fairness of interpersonal treatment and communication during

resource allocation. Finally, Overall Fairness captures a general perception of resource allocation fairness. This method provides a multidimensional approach to understanding fairness perceptions within organizational contexts.

The fairness in the education process is quantitatively assessed using the education process scale developed by Baydas and Cicek (2019). This scale features seven components rated on a 1-7 scale (Strongly Disagree to Strongly Agree), encapsulating dimensions such as equal opportunities for different backgrounds, fair and unbiased grading and evaluation, equal accessibility to educational resources, fair and impartial treatment by teachers, support and accommodations for special needs, meritbased and non-discriminatory admissions, and promotion of diversity and inclusivity in policies and practices. Each item is designed to evaluate participants' perceptions of fairness within the educational context, ranging from accessibility of resources to the inclusivity of policies, thus offering a comprehensive measure of educational equity and justice.

The measurement of the adoption of online education platforms for education equality utilizes a sixitem scale from Wang et al. (2021) and Nayak et al. (2022), reflecting critical aspects that contribute to equitable online learning environments. These dimensions include access and availability, digital literacy and support, personalization and flexibility, inclusivity and diversity, equity and affordability, and empowerment and engagement. Each item is rated on a 1-7 Likert scale, where 1 signifies Strongly Disagree and 7 signifies Strongly Agree. This scale aims to evaluate the platform's capability to overcome geographical and financial barriers, enhance digital literacy, offer personalized learning experiences, promote inclusivity and diversity, ensure affordability, and foster active learner engagement. The method provides a comprehensive approach to assessing how online education platforms contribute to or detract from educational equity.

3.3 Data analysis method

This study uses data statistical tools to conduct descriptive statistical analysis, reliability and validity analysis, confirmatory factor analysis, model fitness analysis, structural equation model, and path analysis.

4. Results

4.1 Reliability and validity

Table 2 presents Cronbach's $\alpha = .750$, for a scale comprising 24 items. Academically, a Cronbach's Alpha of .750 indicates that the scale has acceptable internal consistency, suggesting that the items within the scale are sufficiently correlated with each other and collectively measure a cohesive construct. The value falls within the commonly accepted range for reliable measures (.70 to .90) (Mueller & Hancock, 2018), indicating that the scale is reliable for research purposes.

Table 2. Reliability Statistics

Cronbach's Alpha	N of Items
.750	24

Table 3 reports KMO value of .948 is exceptionally high, suggesting that the dataset is very well suited for factor analysis. The Approximate Chi-Square value is 5885.277 with 276 degrees of freedom, and the significance level is .000. The very low significance level (Sig. < .05) leads to the rejection of the null hypothesis, suggesting that there is a significant relationship among variables, further supporting the suitability of the data for factor analysis. The results imply that the data are likely to produce meaningful and reliable factor solutions, making factor analysis a viable method for exploring the underlying dimensions of the dataset (Mueller & Hancock, 2018).

Table 3. KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.948
Bartlett's Test of Sphericity	Approx. Chi-Square	5885.277
df		276
Sig.		.000

4.2 Confirmatory factor analysis

Table 4 presents the convergent validity of a measurement model by examining latent variables associated with the digital divide (DD), fair resource allocation (FR), fairness in the education process (FE), and adoption of online education platforms for education equality (AO). Convergent validity is assessed through factor loadings, composite reliability (CR), and average variance extracted (AVE).

Factor loadings represent the correlation between observation indicators (e.g., DD1, FR1) and their respective latent variables. A factor loading of 0.7 or higher is generally considered indicative of a strong relationship. In this table, all observed indicators show strong loadings (ranging from 0.735 to 0.801) on their respective latent variables, suggesting that each indicator is a good measure of its latent variable.

Composite Reliability (CR) assesses the reliability of the latent variable measured by its indicators. A CR value above 0.7 is considered acceptable, indicating good internal consistency. The CR values reported here (0.903

for DD, 0.846 for FR, 0.914 for FE, and 0.884 for AO) are all well above this threshold, demonstrating excellent reliability for each construct.

Average Variance Extracted (AVE) measures the amount of variance captured by the latent variables from their indicators relative to the amount due to measurement error. An AVE value above 0.5 suggests that more than half of the indicators' variance is explained by the latent variable, which is desirable for demonstrating convergent validity. The AVE values provided (0.571 for DD, 0.579 for FR, 0.602 for FE, and 0.560 for AO) exceed this criterion, indicating a strong level of convergent validity across all constructs.

Table 4 affirm strong convergent validity within the measurement model. The factor loadings demonstrate that each indicator is a valid measure of its corresponding latent variable. The high CR values across all latent variables indicate that the model has excellent internal consistency. Lastly, the AVE values confirm that a significant portion of the variance in the indicators is accounted for by the latent variables, underscoring the constructs' adequacy in capturing the phenomena they are intended to measure. This validation supports the model's theoretical underpinnings and its empirical applicability in studying the relationships between digital divide, fair resource allocation, fairness in education, and the adoption of online education platforms for education equality.

Table 4. Convergence Validity

	Observation indicators	Factor loading	CR	AVE	Latent variables
	DD1	0.748			
	DD2	0.762			
	DD3	0.772			
	Digital Divide	DD4	0.753	0.903	0.571
		DD5			
		DD6			
		DD7			
	FR1	0.776			
	Fair resource	FR2	0.736		
	0.846			0.579	
	allocation	FR3	0.761		
		FR4			
	FE1	0.801			
	FE2	0.771			
	FE3	0.768			
	Fairness in the				
	FE4	0.787	0.914	0.602	
	education process				
		FE5			
		FE6			
	FE7	0.748	0.749		
	Adoption of				
	AO2	0.760			
	online education				
	AO3	0.734	0.884	0.560	
	platform for				
	AO4	0.759			
	education equality				
	AO5	0.737			
	AO6	0.751			

Note: DD: Digital Divide; FR: Fair resource allocation; FE: Fairness in the education process; AO: Adoption of online education platform for education equality.

Discriminant validity assesses the extent to which a construct is truly distinct from other constructs within the model, typically by showing that it shares more variance with its own indicators than with those of other constructs (Cheung, Cooper-Thomas, Lau, & Wang, 2023). The diagonal elements (in bold) represent the square root of the Average Variance Extracted (AVE) for each latent variable, which are .756 for DD, .761 for FR, .776 for FE, and .748 for AO. These values are compared against the off-diagonal elements, which represent the correlations between the constructs. According to the Fornell-Larcker criterion, for discriminant validity to be established, the square root of the AVE of each construct (diagonal elements) should be larger than the correlations (off-diagonal elements) between that construct and any other construct.

Digital divide, the square root of AVE (.756) is higher than its correlations with FR (-0.467), FE (-0.467), and AO (-0.529), meeting the criterion for discriminant validity.

Fair Resource Allocation, the square root of AVE (.761) exceeds its correlations with DD (-0.467), FE (0.470), and AO (0.508), supporting discriminant validity.

Fairness in the education process, the square root of AVE (.776) is greater than its correlations with DD (-0.467), FR (0.470), and AO (0.544), indicating discriminant validity.

Adoption of online education platform for education equality, the square root of AVE (.748) surpasses its correlations with DD (-0.529), FR (0.508), and FE (0.544), affirming discriminant validity.

Table 5 demonstrate that each construct shares more variance with its indicators than with those of other constructs in the model, successfully establishing discriminant validity. This confirms that the constructs are empirically distinct, each measuring different aspects of the model related to the digital divide, resource allocation fairness, education process fairness, and the adoption of online education platforms for ensuring education equality. This distinction is critical for theoretical clarity and for the integrity of subsequent analyses examining the relationships between these constructs.

Table 5. Discriminant validity test

Note: The diagonal is the square root of the corresponding dimension AVE.

Latent variables	1	2	3	4
Digital Divide	0.756			
Fair resource allocation	-0.467	0.761		
Fairness in the education process	-0.467	0.470	0.776	
AO	-0.529	0.508	0.544	0.748

DD: Digital Divide; FR: Fair resource allocation; FE: Fairness in the education process; AO: Adoption of online education platform for education equality.

Table 6 showcases the fit indices from a confirmatory factor analysis (CFA), juxtaposed with their reference standards for a good model fit. $\chi^2/df = 0.981 (<3)$ indicates a good fit between the hypothesized model and the observed data. RMSEA=0.000 (<0.08) suggest a good fit, with lower values indicating better fit. GFI and AGFI greater than 0.9 and 0.85, respectively, indicate a good fit. The results of 0.958 for GFI and 0.949 for AGFI both exceed these thresholds, indicating a strong fit of the model to the data. NFI, TLI, and CFI, values above 0.9 are indicative of a good model fit. The results of 0.960 for NFI, 1.001 for TLI, and 1.000 for CFI not only meet but exceed these reference standards, signifying an exceptional fit. This robust model fit is crucial for the validity of subsequent analyses derived from the model, providing a solid foundation for drawing inferences about the relationships between constructs.

Figure 1 construct the confirmatory factor analysis model.

Table 6. Confirmatory factor model fit metrics

Fit index	χ^2/df	RMSEA	GFI	AGFI	NFI	TLI	CFI
Reference standards	<3	<0.08	>0.9	>0.85	>0.9	>0.9	>0.9
Result	0.981	0.000	0.958	0.949	0.960	1.001	1.000

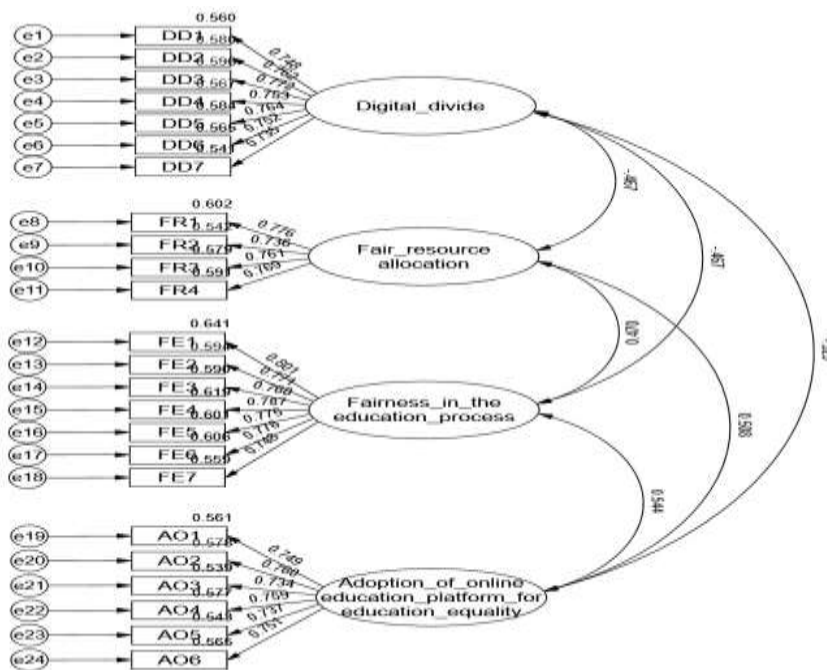


Figure 1. Measurement model analysis

4.3 Structural equation model

Table 7 presents the fit indices for a structural equation model (SEM), comparing them against widely accepted reference standards for model fit. The results show a $\chi^2/df = 1.113 (<3)$, indicating a good fit. The RMSEA=0.016 (<0.08), suggesting a close fit between the model and the observed data. GFI and AGFI values exceed 0.9 and 0.85, respectively, demonstrating a strong model fit, while NFI, TLI, and CFI indices are above 0.9, further confirming the model's adequacy in capturing the underlying data structure. Collectively, these metrics indicate an excellent fit of the SEM to the data.

Table 7. Model fit metrics for structural equation model

Fit index	χ^2/df	RMSEA	GFI	AGFI	NFI	TLI	CFI
Reference standards	<3	<0.08	>0.9	>0.85	>0.9	>0.9	>0.9
Result	1.113	0.016	0.952	0.942	0.954	0.995	0.995

Table 8 summarizes the results from a structural equation model (SEM) path analysis, testing hypotheses concerning the relationships between the Digital Divide (DD), Fair Resource Allocation (FR), Fairness in the Education Process (FE), and Adoption of Online Education Platforms for Education Equality (AO). The findings reveal significant paths between all hypothesized relationships. The negative paths from DD to FR ($\beta = -0.481, p < 0.001$), DD to AO ($\beta = -0.275, p < 0.001$), and DD to FE ($\beta = -0.481, p < 0.001$) indicate that increases in the digital divide lead to decreases in fair resource allocation, adoption of online education platforms, and fairness in the education process, respectively, supporting hypotheses H1, H2, and H3. Conversely, positive paths from FR to AO ($\beta = 0.243, p < 0.001$) and FE to AO ($\beta = 0.316, p < 0.001$) demonstrate that improvements in fair resource allocation and fairness in the education process contribute to greater adoption of online education platforms, thereby supporting hypotheses H4 and H5. These results are statistically significant ($p < 0.001$), indicating a high level of confidence in the findings and their implications for understanding the dynamics affecting the adoption of online education platforms in the context of digital divide and educational equity.

Table 8. Structural equation model path test

Hypothesis	Path	Estimate	β	S.E.	C.R.	P	Results
H1	DD→FR	-0.488	-0.481	0.057	-8.586	***	Supported
H2	DD→AO	-0.262	-0.275	0.057	-4.597	***	Supported
H3	DD→FE	-0.510	-0.481	0.057	-8.968	***	Supported
H4	FR→AO	0.228	0.243	0.051	4.471	***	Supported
H5	FE→AO	0.285	0.316	0.048	5.976	***	Supported

Note: DD: Digital Divide; FR: Fair resource allocation; FE: Fairness in the education process; AO: Adoption of online education platform for education equality.

***: $p < 0.001$

Table 9 details the outcomes of a mediation effect bootstrap test, which examines the indirect effects within the structural equation model, specifically testing the mediation hypotheses H6 and H7. The bootstrap method provides an estimate of the effect size and its standard error (SE), along with biascorrected 95% confidence intervals (CI) for the mediation paths. For H6, the mediation path from the Digital Divide (DD) through Fair Resource Allocation (FR) to the Adoption of Online Education Platforms for Education Equality (AO) shows an effect size of -0.111 with a standard error of 0.040. The 95% confidence interval ranges from -0.211 to -0.047, not encompassing zero, thereby supporting the mediation hypothesis. Similarly, path from DD through Fairness in the Education Process (FE) to AO reveals an effect size of -0.145, with a SE of 0.040 and a 95% CI from -0.244 to -0.081. The confidence intervals for both hypotheses are entirely below zero, indicating significant negative mediation effects and supporting the hypothesized mediation roles of FR and FE in the relationship between DD and AO. These results affirm the substantial mediating effects of fair resource allocation and fairness in the education process on the impact of the digital divide on the adoption of online education platforms.

Table 9. Mediation effect bootstrap test

Hypothesis	Mediation path	Effect size	SE	Bias-Corrected		Results
					95%CI	
H6	DD→FR→AO	-0.111	0.040	-0.211	-0.047	Supported
H7	DD→FE→AO	-0.145	0.040	-0.244	-0.081	Supported

All in all, figure 2 portrays the structural equation model to understand the path of digital divide affecting the adoption of online platform for education equality.

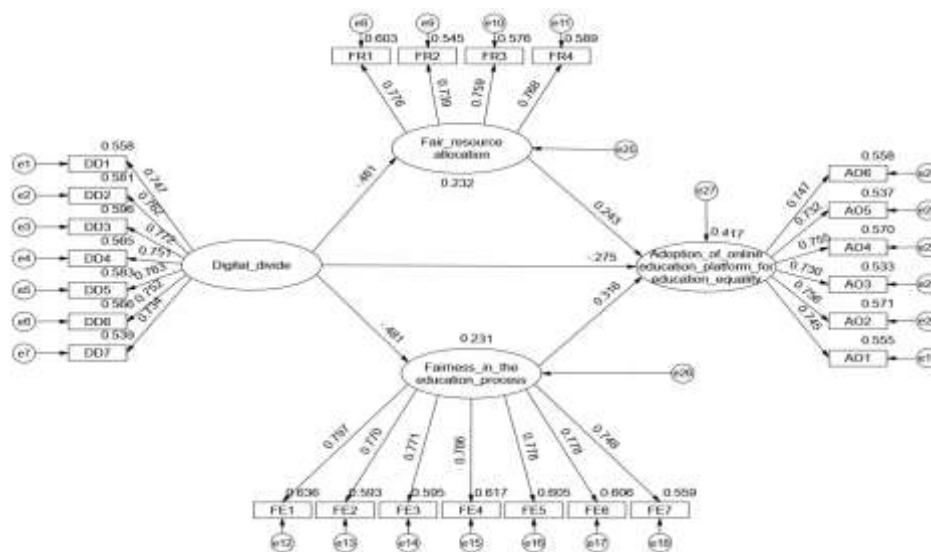


Figure 2. Path Diagram for the structural equation model.

5. Discussion and conclusion

5.1 Theoretical implication

This study illuminates the complex relationship between the digital divide and higher education students' engagement with online education platforms, particularly in the context of education for sustainable development. The study's revelation that the digital divide negatively impacts students' adoption of online education platforms through the mediating effects of equity in resource allocation and fairness in the educational process provides a nuanced understanding of the barriers to education equality in the digital age. Comparatively, Singh et al. (2022) also emphasize the role of e-learning in mitigating the digital divide for education dissemination, albeit with a focus on decision analysis. While Singh et al. underline the potential of e-learning to bridge gaps, our study further dissects the mechanisms—specifically, equity and fairness—that can either facilitate or hinder this bridging process. Yu (2020) discusses the algorithmic divide, touching on issues of equality in the digital realm. While Yu concentrates on the broader implications of artificial intelligence, our findings complement this discussion by demonstrating how digital divides in education specifically affect equitable access to learning technologies. The study by Kerras et al. (2020) on the gender digital divide aligns with our findings in highlighting the significance of addressing digital divides for sustainable development. However, our research adds to this by detailing how equity in resource allocation and educational process fairness serve as vital links in the chain connecting the digital divide to education engagement. Faturoti (2022) adopts a human rights perspective on internet access during COVID19, stressing the importance of online learning accessibility. This perspective resonates with our findings, emphasizing that equitable resource distribution and fairness in education are fundamental rights that need safeguarding to ensure effective online learning. Zheng & Liang (2017) explore the digital divide's impact on educational equality through an information system success model, providing insights into the technological factors influencing education access. Our study builds on this by identifying specific educational and resource distribution factors that mediate the digital divide's impact on learning platform adoption. Finally, Sunny et al. (2024) focus on the educational technology divide in India shares a thematic similarity with our research in its focus on access, adoption, and equity in digital learning. Our findings contribute to this discourse by elucidating the mediating roles of fairness and equity, suggesting targeted areas for intervention to improve digital learning engagement.

Overall, while existing literature covers various facets of the digital divide and education equality, this study uniquely contributes by detailing how fairness in resource allocation and the educational process mediates the relationship between the digital divide and the adoption of online education platforms, offering actionable insights for enhancing digital education engagement.

The results of this study significantly enrich digital divide theory by elucidating how the divide extends beyond mere access to technology, deeply impacting the engagement with online education platforms through the nuanced pathways of resource allocation equity and educational process fairness. Traditionally, digital divide theory has primarily focused on access to and usage of Information and Communication Technology (ICT) (Aissaoui, 2022). However, by identifying the mediating roles of resource allocation and educational fairness, this research highlights a more complex interaction where the digital divide also encompasses the quality and fairness of educational opportunities provided through digital means. This insight extends the theory by

suggesting that interventions aimed at bridging the digital divide need to consider not only technological access but also the equitable distribution of educational resources and the fairness of educational practices. Such a comprehensive approach could significantly reduce the educational disparities exacerbated by the digital divide, thereby contributing to a more nuanced understanding and strategic solutions to overcome digital disparities.

Moreover, the findings contribute to educational equity theory by demonstrating that equity in resource allocation and fairness in the educational process are not just ethical imperatives but are essential for enhancing the adoption of online education platforms, particularly in the realm of education for sustainable development. This aligns with and expands educational equity theory, which advocates for equal opportunities and outcomes in education, by showing how equity and fairness within the digital education domain can facilitate or hinder educational engagement and equality. The mediating effect observed in this study underscores the importance of considering the educational process's fairness and resource distribution's equity as critical factors in designing and implementing digital education strategies. This suggests that efforts to promote educational equity in the digital age must address the broader socio-economic and institutional structures that influence resource allocation and educational practices. By doing so, the research provides empirical evidence that strengthens educational equity theory, offering a pathway through which digital education can contribute to leveling the educational playing field, thereby making a significant leap towards achieving true educational equality in the digital era.

5.2 Practical implications

The demonstrated negative impact of the digital divide on the adoption of online education platforms highlights an urgent need for targeted policies that go beyond providing technological access. Specifically, the mediation effects of fair resource allocation and educational process fairness in mitigating the digital divide's adverse effects underscore the necessity for comprehensive strategies that encompass equitable resource distribution and the implementation of fair educational practices. Policymakers should therefore prioritize initiatives that ensure equitable access to digital devices and internet connectivity, alongside the development of transparent and inclusive policies for resource allocation and educational opportunities. This approach not only addresses the technological aspects of the digital divide but also the socio-economic and institutional barriers that perpetuate educational inequalities.

Educational institutions and online platform providers have a pivotal role to play in operationalizing the study's findings. The positive influence of equitable resource distribution and a fair educational process on online education platform adoption suggests that institutions should invest in robust support systems for students from diverse backgrounds. This includes offering personalized learning paths, providing digital literacy training, and ensuring that online content is accessible and inclusive. Additionally, fostering an environment that values diversity and promotes inclusivity can enhance students' engagement and success in online learning environments. For online education platforms, this translates into designing features that accommodate a wide range of learning styles and needs, thereby making education more accessible and equitable.

Lastly, the research underscores the importance of collaborative efforts between governments, educational institutions, and technology providers in bridging the digital divide. Such collaborations can lead to the development of cross-sectoral strategies that not only provide the necessary technological infrastructure but also foster an educational culture that values and promotes fairness and equity. For instance, public-private partnerships could facilitate the deployment of affordable internet services and digital devices to underserved communities, while educational policies and curricula could be co-developed to ensure they are relevant, equitable, and capable of preparing students for a digital future. By implementing these strategies, stakeholders can significantly contribute to reducing educational disparities, enhancing the effectiveness of online education, and promoting sustainable development through education that is truly accessible to all.

5.3 Research limitations and future studies

The research was conducted with a sample drawn from students across five prestigious universities in China. While this approach ensures a high degree of academic engagement and diversity, it may not fully capture the experiences of students from less prestigious institutions or vocational schools, who may face different challenges related to the digital divide. Future studies could broaden the participant base to include a wider range of educational institutions, including community colleges and vocational schools, to capture a more diverse range of experiences and challenges in online education.

The focus on Chinese universities limits the generalizability of the findings to other cultural and socio-economic contexts. Digital divide issues and the effectiveness of resource allocation and educational fairness in mitigating these divides may vary significantly across different countries and regions due to varying levels of infrastructure development, internet accessibility, and educational policies. Future research could explore these dynamics in other geographical areas, particularly in low-income countries and regions with stark digital divides, to compare and contrast with the findings of this study.

The study primarily utilized online surveys to collect data, which, while efficient, might not capture the depth and complexity of students' experiences and perceptions. Qualitative methods such as interviews, focus groups, or case studies could provide richer, more nuanced insights into how the digital divide affects students'

engagement with online education and how equitable practices can mitigate these effects. Additionally, longitudinal studies could explore how changes in technology access and educational policies over time affect the digital divide and online education engagement.

While this study builds on digital divide theory and educational equity theory, it could be enriched by incorporating additional theoretical frameworks. For example, theories of social capital could deepen understanding of the role of social support networks in online education engagement. Similarly, applying theories related to motivation and self-efficacy could offer further insights into how personal and psychological factors interact with structural conditions to influence online learning engagement. Future studies could integrate these theoretical perspectives to provide a more comprehensive understanding of the factors affecting engagement with online education in the context of the digital divide.

Addressing these limitations in future research will not only enhance understanding of the complex dynamics at play but also inform more effective interventions to promote equitable access to and engagement with online education.

5.4 Conclusion

This study has critically examined the impact of the digital divide on higher education students' engagement with online education platforms, with a special focus on education for sustainable development. Utilizing a robust methodological framework that combined online surveys with structural equation modeling, data were collected from a diverse cohort of 449 students across five prestigious Chinese universities. The findings underscore the detrimental effects of the digital divide on the adoption of online education platforms, mediated significantly by the equity of resource allocation and the fairness of educational processes. This research not only extends digital divide and educational equity theories by incorporating the mediating roles of resource allocation and educational fairness but also provides actionable insights for policymakers, educators, and online platform providers to enhance online education engagement through equitable practices. Moving forward, this study's revelations beckon further investigation beyond the Chinese context, advocating for a broader inclusion of diverse educational settings and populations. Future research should also explore a mix of qualitative and quantitative methods to unravel the complexities of online education engagement in the digital age. By bridging the digital divide through equitable resource distribution and fair educational practices, this work paves the way for a more inclusive and accessible online education ecosystem, contributing significantly to the discourse on sustainable development through education.

Author Contributions

Conceptualization, Z.H. and T.C.; methodology, A.P., Z.H. and T.C.; validation, A.P., Z.H., and T.C.; formal analysis, A.P., Z.H., and T.C.; investigation, A.P., Z.H., and T.C.; writing—original draft preparation, A.P.; writing—review and editing, Z.H., and T.C.; visualization, A.P., Z.H. and T.C.; supervision, Z.H., A.P. and T.C.; project administration, T.C.; funding acquisition, T.C. All authors have read and agreed to the published version of the manuscript.

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

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