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Unveiling the impact of ICTs as a catalyst of technological innovation on well-being under gender inequality's moderating role

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ABSTRACT

Information and Communication Technologies (ICTs) represent a significant technological advancement that enhances communication, access to information, and socio-economic interactions. By analysing the impact of ICTs on well-being across nations, this study explores an essential aspect of technology innovation's role in improving individuals' overall quality of life—covering both subjective and objective well-being. This study aims to analyse the influence of ICTs on well-being while considering the moderating effect of gender inequality. The research uses panel data from 185 countries covering the years 2005 to 2021 to explore the relationship between ICTs and well-being concerning gender inequality, using both subjective (e.g., life satisfaction) and objective (e.g., prosperity) well-being indicators. The objective was to gain a deeper understanding of the complex relationship between ICTs and well-being, focusing on the moderating role of gender inequality. The findings suggest that there is a positive correlation between ICT impact and well-being, which is amplified as gender inequality decreases. These findings held consistent when using different measures of objective well-being and introducing new variables for comparison. The study offers valuable insights into the role of gender equality – an essential component of social innovation - in upholding the positive effects of ICTs on well-being, assessed from both subjective and objective perspectives.

Introduction

The use of new information and communication technologies (ICTs) such as mobile phones, computers, tablets, televisions, and the Internet has significantly increased worldwide in the past few decades. This growth has been further accelerated by the pandemic of 2020–2022, which has impacted the entire world. Undoubtedly, the pandemic has highlighted the importance of digital transformation while also increasing the need to address concerns about the impact of digital technologies on our well-being. This has created a new rationale and relevancy for digital transformation and using of technologies, as organizations and individuals alike are grappling with the challenges and opportunities presented by the digital era. Furthermore, the pandemic has heightened the urgency of cultivating digital well-being, as the

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boundaries between personal and professional life become increasingly blurred in the digital realm (Dennis, 2021).

Previous literature provides quite relevant contributions regarding the effects of ICTs adoption on different socio-economic aspects such as economic growth (Jayaprakash & Pillai, 2022), environmental sustainability (Shobande & Ogbeifun, 2022), unemployment (Ahuru et al., 2023), income inequality (Asongu & Odhiambo, 2019; Richmond & Triplett, 2018), consumption inequality (Zhang et al., 2020), employees' effectiveness and well-being (Wang et al., 2020; Day et al., 2012), quality of life among indigenous communities (Hasan et al., 2022), or health outcomes (Văidean and Achim, 2022).

Access to ICT has enabled certain countries to become outsourcing hubs, creating employment opportunities for their citizens that would not have been possible otherwise, thus having a broader social impact on society (Ganju et al., 2016). Although the adoption rate of ICTs in developing countries is relatively low, the positive socio-economic effects of its use are evident and continuously expanding. The impact of ICT on developing countries is multifaceted. It includes economic growth, growing employment opportunities, improved access to education and healthcare, and enhanced communication and collaboration among individuals and organizations (Ma et al., 2023a). Exploring the impact of ICTs on well-being is a challenging task due to the variety of sources that need to be considered to understand the relationship between them. Additionally, ICTs can affect well-being from at least two perspectives: subjective and objective. As ICTs comprise a diverse range of applications, their impact on human well-being will depend on the specific usage of the ICTs (Maiti & Awasthi, 2020).

The concept of well-being has been studied from various angles. Still, two main paradigms are commonly used: *subjective well-being* and *objective well-being* perspective (Maiti & Awasthi, 2020; Joshanloo et al., 2019). Both paradigms complement each other and offer unique perspectives on well-being. The subjective perspective focuses on an individual's self-reported experiences and evaluations of their life satisfaction, while the objective perspective considers external factors such as personal growth, income or wealth, self-realization, health status, and material possessions (Maiti & Awasthi, 2020). While different perspectives may exist, each one is significant in understanding the complex nature of well-being. Unfortunately, previous global well-being assessments have primarily focused on measures of subjective well-being, such as life satisfaction (Diener & Seligman, 2018). Indicators of *objective well-being* have been largely overlooked in global well-being studies (Joshanloo et al., 2019). Our study aims to explore the multifaceted nature of well-being under the impact of ICTs. To achieve this, we used a subjective well-being indicator, namely happiness (life satisfaction), as the dependent variable of the main analysis. In addition, to ensure the validity of our findings, we conducted a robustness check. We replaced the dependent variable with another indicator, such as prosperity, which is more suitable for measuring objective well-being.

Despite the paramount significance of well-being, scholarly inquiry into the intricate dynamics of the relationship between well-being and technology remains relatively limited. The dearth of research elucidating the interplay between technology and well-being necessitates a deeper exploration of the subject matter, particularly considering the growing ubiquity of technology in contemporary society (Kafaee et al., 2021).

Gender is often included as a control variable in studies analysing the factors that affect well-being. This is because previous research (Danish & Nawaz, 2022; Nie et al., 2021; Yan & Wen, 2020; Ciziceno & Travaglino, 2019; Tay et al., 2014; Jiang et al., 2012) suggests that the perception of well-being varies between genders. Some studies indicate that policies aimed at reducing gender inequalities can significantly improve well-being, as noted by Asadullah et al. (2018). To the best of our knowledge, there have been no studies managed to investigate the influence of ICTs on well-being, with a specific emphasis on how gender inequality may moderate this relationship. Therefore, we believe it is crucial to examine how ICTs affect well-being while considering the moderating effect of gender inequality. In doing so, we aim to move beyond treating gender as a mere control variable and gain a better understanding of this complex relationship.

There is a clear lack of empirical evidence on how ICT adoption and diffusion affect well-being under the moderating role of gender inequality. To bridge this gap in the literature, we analyse the impact of ICTs adoption (such as the use of Internet, mobile cellular and fixed telephone subscriptions, secure Internet servers, and fixed broadband subscriptions) on well-being while using gender inequality as a moderating variable. To the authors' current knowledge, the influence of ICT adoption on various measures of well-being—both subjective and objective—has not been examined in the context of the moderating role of gender inequality. Therefore, the originality and key contributions of this study to this field of research can be summarized in the following directions: Firstly, to the best of our knowledge, this study is the first to focus on the impact of ICT adoption on well-being across a large global sample of 185 countries. Additionally, to provide a more thorough analysis of how ICTs affect well-being, we chose to use indicators that capture both subjective measures, such as life satisfaction, and objective measures, such as prosperity. Our decision to employ these indicators was informed by the need to develop a more robust and accurate understanding of the impact of ICTs on well-being. By incorporating subjective and objective measurements in our analysis, we hope to shed light on the multifaceted and complex relationship between ICTs and well-being with a focus on the moderating role of gender inequality. Thirdly, this study reveals the connection between ICT adoption and well-being, while also considering the moderating role of gender inequality, which has been less explored in the existing literature. The study provides strong empirical evidence that the reduction of differential treatment between men and women leads to a more positive impact of ICT on well-being, as measured by both subjective and objective indicators. Both main analysis and robustness checks revealed a positive correlation between the direct impact of ICT on well-being and the reduction of gender inequality. In other words, the more significant the reduction in gender inequality, the more pronounced the positive impact of ICT on well-being. This finding highlights the importance of promoting gender equality to enable the positive effects of ICT on well-being.

The paper is structured in the following way: In Section 2, we provide a summary of the relevant literature review that supports the analysed hypothesis. Then, Section 3 presents our data and research methodology. In Section 4, we disclose our obtained results and discuss the main empirical findings, as well as the robustness checks. Finally, in Section 5, we conclude the paper by providing a summary of the main findings and a brief discussion of the policy implications, limitations, and avenues for further research.

Literature review

In the following section, we will provide a concise synthesis of prior contributions concerning the impact of Information and Communication Technologies (ICTs) on well-being, as well as the role of gender inequality in moderating this relationship. Our focus will primarily be on studies published in Web of Science and Scopus over the last ten years, given the remarkable advancements in this area of research. This approach aims to frame our hypotheses and contextualize our findings within the existing relevant literature.

ICTs and well-being

There is a growing body of literature that investigates the effects of ICTs adoption on various socio-economic factors worldwide (Ahuru et al., 2023; Barbier, 2023; Ma et al., 2023a,b, Shobande and Ogbeifun, 2022; Ejemeyovwi et al., 2021; Asongu & Odhiambo, 2019). While ICTs adoption and diffusion have been transformative for developed

countries, even developing countries with relatively low adoption rates experience positive socio-economic outcomes from it (Ma et al., 2023a; Graham and Nikolova, 2013).

Over the past few decades, a significant amount of research has been conducted on the relationship between ICTs adoption and well-being, with a focus on both objective and subjective measures. The existing body of literature has identified two primary streams of analysis, as previously pointed out by Ma et al. (2023a).

The first strand of research focuses on measuring well-being from a subjective perspective, such as happiness, life satisfaction, and overall quality of life (e.g. Ma et al., 2023a; Zhu et al., 2022; Castellacci & Schwabe, 2020; Castellacci & Tveito, 2018; Nie et al., 2021, 2017; Ganju et al., 2016; Graham & Nikolova, 2013). Many studies have investigated the relationship between the adoption of ICT and an individual's subjective well-being, which is their overall evaluation of life based on cognitive and affective factors (e.g. Zhu et al., 2022; Nie et al., 2021, 2017). The study conducted by Nie et al. (2017) examined the relationship between internet usage and subjective well-being, including factors such as life satisfaction, happiness, and depression, using a sample of Chinese individuals aged 16 to 60. The study suggested that the impact of internet use on subjective well-being is dependent on two main factors: the purpose of internet use and the extent to which individuals feel that their internet use is affecting other activities in their lives. According to Zhu et al. (2022), adopting ICT and high individual income demonstrate a significant positive association with elevated happiness and life satisfaction levels. Conversely, these factors exhibit a significant negative correlation with stress and loneliness. In a similar vein, Nie et al. (2021) investigated the potential impact of smartphone usage on the quality of life among rural residents in China and found that smartphone usage is positively correlated with both life satisfaction and happiness. Hall (2019) suggested that internet usage has the potential to increase human well-being and happiness, while also reducing inequality, as it allows educated individuals with lower incomes to gain from its use. Castellacci & Tveito (2018) conducted a literature survey to examine the impact of Internet usage on well-being. Their research found that Internet usage can affect well-being in four major ways. Firstly, it can change the way people use their time. Secondly, it introduces new activities. Thirdly, it allows access to information, and fourthly, it can act as a powerful communication tool, impacting various aspects of life. However, the influence of Internet usage on well-being is dependent on personal traits that are unique to each individual, such as psychological functioning, abilities, cultural, and belief frameworks, which act as mediators. Also, the study by Castellacci & Schwabe (2020) found that using the internet, computers, and mobile phones has a positive impact on life satisfaction and well-being.

Several studies have examined the relationship between adopting ICT and subjective well-being on a macroeconomic level, although the number of studies is limited (e.g. Kouladoum et al., 2023; Ganju et al., 2016; Graham & Nikolova, 2013). For instance, Graham & Nikolova (2013) conducted a study using data from the Gallup World Poll (2009–2011) to explore the relationship between technology access and subjective well-being. They found that access to technology positively impacts well-being but with diminishing marginal returns for those who already have much access. The study also revealed that new technology users experienced increased stress and anger. However, countries with higher levels of mobile banking access had higher levels of well-being but also higher levels of stress and anger. Ganju et al. (2016) conducted a study using a fixed-effects model and an instrumental variable approach to investigate the impact of ICT use on a country's well-being. Their findings suggest that ICT can enhance citizens' well-being by promoting social capital and equality. Additionally, it can provide access to health-related information and services, education to underprivileged communities, and facilitation of commercial activities. Interestingly, Ganju et al. (2016) found that mobile phones primarily increase the level of well-being in less-developed countries, while any ICT system increases the level of well-being in more-developed countries. Recently, Kouladoum et al. (2023) conducted a study on 29 African countries to investigate the impact of technology transfers on subjective well-being, using the Lifeladder indicator of happiness as a measure. The study utilized the GMM and IV Tobit models and discovered that technology transfers and investments in academic research exert a significantly positive effect on the subjective well-being of people in African countries.

The second stream of research focuses on how the adoption of information and communication technology (ICT) affects people's well-being from an objective perspective. This is usually measured by looking at external factors such as personal growth, income or wealth, material possessions, health status, income inequality and consumption (e.g. Ma et al., 2023a; Zambianchi, 2023; Leng et al., 2020; Maiti & Awasthi, 2020; Zhang et al., 2020). For instance, Zambianchi (2023) found a positive correlation between Internet and email usage and the well-being indicators which encompasses personal growth, multiple life projects, and satisfactory social relations. The studies' results within the first research stream lack convergence in direction, indicating a potential discrepancy in the findings. Some scholars argue that the use of ICTs can have a positive effect on reducing income and consumption inequality (Ma et al., 2023a), and can also lead to a significant increase in household income (Ma et al., 2023b). However, other researchers (Zhang et al., 2020) posit that internet usage tends to exacerbate consumption inequality.

In a study conducted by Asongu & Odhiambo (2019) at the macro-economic level, 48 African countries were analysed for the period of 2004–2014 to determine if Information and Communication Technologies (ICTs) had a positive impact on reducing inequality. The study utilized ICT proxies such as mobile phone and internet penetration, as well as fixed broadband subscriptions to measure the impact on inequality, as measured by the Atkinson index and the Palma ratio and revealed that these ICTs have a net effect on reducing inequality. Similarly, Asongu et al. (2021) examined the relationship between poverty, inequality, and ICT dynamics in 57 developing countries from 2012 to 2016. They used indicators such as internet access in schools, personal computers, social networks, mobile phones, and internet penetration, as well as fixed broadband subscriptions to measure ICT dynamics. The study found that personal computers, internet access in schools, and internet penetration could promote gender-inclusive education but poverty and inequality levels must be kept in check for these benefits to be realized. Tchamyou et al. (2019) analysed the relationship between income inequality and ICTs in 48 African countries over the period from 1996 to 2014. The study focused on ICTs measurements such as mobile phone subscriptions (per 100 people), Internet subscriptions (per 100 people), and fixed broadband (per 100 people). The findings indicated that ICTs indicators played a significant role in reducing income inequality. Richmond & Triplett (2018) also analysed the correlation between ICT and income inequality, using data from 109 countries spanning the period 2001–2014. The study revealed that the effect of ICT on income inequality varied depending on the particular metric employed to gauge ICT adoption and income inequality. Additionally, the study of Richmond and Triplett (2018) demonstrated that the connection between ICT and income inequality was influenced by various economic and political factors, same as Bauer (2018). Specifically, Richmond & Triplett (2018) confirmed that Internet use and Mobile were associated with a significant reduction in inequality and improvements in well-being, whereas the effects of Broadband did not reach the same significance level.

Ongoing research into the effects of information and communication technologies (ICTs) on subjective and objective well-being is of significant importance to academics, practitioners, and policymakers. While the previous findings suggest that the adoption of ICT has the potential to improve well-being in various ways, it is essential to continue exploring this relationship while also considering potential factors that could significantly moderate their connection. Therefore, we argued that it is critical to conduct further research to identify the precise

mechanisms through which ICTs influence well-being and to investigate the role of potential moderators, such as gender inequality, that may alter the relationship between ICT use and well-being. By conducting such research, we can gain a deeper understanding of the complex relationship between ICT use and well-being and develop evidence-based strategies that provide positive outcomes for individuals and organizations.

Gender inequality and the impact of ICTs on well-being

In recent years, researchers have emphasized the importance of achieving gender equality (Beloskar et al., 2024; Martinez-Garcia et al., 2024; Leung et al., 2020). Gender equality has significant implications for human development, and it is becoming increasingly necessary to implement policies that promote it in the labour market. These policies will enable more women to transition from informal to formal activities (Ndoya et al., 2024). Numerous studies have demonstrated the harmful effects of inequality, such as income and gender disparities, on societies, leading to dysfunction and fragmentation (Ndoya et al., 2024; Kumar, 2022). The negative impacts of inequality are even more pronounced in less-developed countries (Ndoya et al., 2024; Ma et al., 2023a; Castells-Quintana et al., 2019; Mannah-Blankson, 2018; Richmond & Triplett, 2018). As previous researchers (Ma et al., 2023a) have suggested, reducing inequality can be vital in creating more inclusive communities and fostering sustainable human development. By doing so, it can contribute to the proper achievement of the United Nations' Sustainable Development Goals, especially those related to *"good health and well--being*", "*gender equality"* and "*reduced inequalities"*.

The topics of gender equality and well-being are of great importance to researchers, government officials, and policymakers alike. Recently, Ndoya et al. (2024) conducted a study that analysed data gathered from 84 developing and emerging countries spanning from 2006 to 2018. Their objective was to investigate the relationship between gender equality and levels of well-being proxied by happiness. Their results indicate that gender equality has a positive impact on happiness in developing and emerging countries. Furthermore, the impact of gender equality on happiness is more pronounced in high-income or democratic countries compared to low-income or non-democratic ones (Ndoya et al., 2024).

It has long been widely acknowledged that ICTs can serve as a potent tool for the empowerment of women and the promotion of gender equality (Kiondo, 2007). Despite this recognition, however, women continue to face several obstacles that hinder their effective access to and use of ICTs, and the progress is slow. The lack of access to ICTs and the related infrastructure, coupled with the dearth of digital literacy skills among women, remain significant barriers to their effective use of technology. Additionally, social and cultural norms, gender discrimination, and economic disparities further exacerbate the digital divide, leaving women at a disadvantage in the digital age. Furthermore, the digital gender gap is an emerging concept that is gaining momentum. It refers to the discrepancy in technology and internet access between different groups, with women often having less access than their male counterparts (Campos & Scherer, 2024; Shah & Krishnan, 2023; Khera et al., 2022). This issue has significant implications for businesses and academia alike. According to Khera et al. (2022), advancing women's financial inclusion is a potent strategy for promoting gender equality and progress. However, realizing this vision necessitates a deep understanding of women's lived experiences. This is because many women lack fundamental resources, like mobile phones and internet access, that are necessary for using digital services. Additionally, women across the globe have low levels of digital and technology-related literacy, with only approximately 15% of women involved in STEM (science, technology, engineering, and mathematics) fields (Khera et al., 2022). In the same line, Shah & Krishnan (2023) noted unequal mobile phone and internet access for men and women. As of 2022, 62% of men worldwide use the internet compared to 57% of women. Furthermore, according to recent research (Shah & Krishnan, 2023; Wu & Kane, 2021), the proliferation of mobile devices, the internet, and other digital platforms among women has a direct positive correlation with their overall well-being and creates new opportunities.

As previous authors have argued (Asongu & Odhiambo, 2019), the current body of empirical research focusing on the relationship between ICTs and inequality is limited. Although gender equality and the role of information and communication technology (ICT) in promoting well-being are widely recognized, empirical studies examining their relationship together are limited. Most of the existing studies focus on analysing how ICTs are utilized to empower, educate, employ, and promote entrepreneurship and leadership opportunities for women in contemporary society (e.g. Rahman et al., 2023; Lechman & Popowska, 2022; Bosch et al., 2021; Palomares-Ruiz et al., 2021).

Furthermore, to the best of our knowledge, no empirical studies have yet emerged that examine the relationship between ICTs and well-being, with a focus on the moderating role of gender inequality. This represents a significant gap in our understanding of the intersection between these variables and highlights the need for further research in this area. In a novel approach, we propose to investigate the possibility of whether the relationship between information and communication technologies (ICTs) and well-being may be moderated by gender inequality. To this end, we put forward the following hypothesis to be tested empirically:

Hypothesis. The higher the gender inequality becomes, the lower the effect of ICT proxies on well-being.

Our belief is that this inquiry is crucial, considering the growing reliance on ICTs in both personal and professional domains and the persistent gender disparities that exist in their use and outcomes. By testing this hypothesis, we may gain insights into the ways in which gender equality shapes the digital landscape and inform policies and interventions aimed at reducing inequalities and promoting well-being for all.

Data and research methodology

The sources of data

This study utilized secondary data from a large sample of 185 countries worldwide between 2005 and 2021. The study's sample and timeline were limited by the availability of specific data. Data on subjective well-being were collected from the World Happiness Database of Life Ladder Indicators (Helliwell et al., 2022) and data on objective well-being were collected from the Legatum Prosperity Report (Legatum Institute, 2023). Data on the independent and control variables were obtained from the World Bank Development Indicators (World Bank, 2023), while the Gender Inequality Index, used as a moderating variable, was selected from Human Development Reports developed by the United Nations Development Programme (UNDP, 2023). Table 1 provides a description of every variable considered, along with their sources and units/scales of measurement. Then, Table 2 provides the descriptive statistics of these variables and correlation coefficients among variables are presented in Table 3.

Variables selection and justification

Dependent variable – measuring well-being

The topic of well-being has been thoroughly explored in previous literature (e.g. Maiti & Awasthi, 2020; Joshanloo et al., 2019; Barrington-Leigh & Escande, 2018; Otoiu et al., 2014). Although it has undergone significant development, there is no universally accepted approach. Well-being encompasses not only objective factors like income but also subjective factors such as emotions and overall satisfaction with life, which are influenced by a variety of conditions related to economic outcomes, health, culture, happiness, prosperity, and social connections (Maiti & Awasthi, 2020).

Table 1
Description of variables.

Variables	Code	Description	Unit/ Scale	Source
Dependent variable				
Happiness index (used in the main analysis)	**Happy**	This survey uses the Cantril ladder, which asks participants to rate their life satisfaction on a scale of 0 to 10, with 10 being the best and 0 being the worst.	Score from 0 (worst) to 10 (best)	Helliwell et al. (2022) https://worldhappiness.report/ed/2022/
Legatum Prosperity (used in robustness tests)	**PROSP**	The Legatum Prosperity Index is a tool used to evaluate countries based on how well their residents can economically and socially thrive. It considers a wide range of factors that contribute to a truly prosperous life, going beyond traditional economic measures like GDP per capita. The Index score provides a comprehensive assessment of a country's level of prosperity.	Score	https://www.prosperity.com/about/methodology Legatum Institute (2023)
Independent variables				
Individuals using the Internet (% of population)	**Internet**	Individuals who have used the Internet in the last 3 months, via a computer, mobile phone, or other devices.	%	World Bank (2023)
Mobile cellular subscriptions (per 100 people)	**Mobile**	Mobile cellular telephone subscriptions are public mobile telephone services that provide access to the Public Switched Telephone Network (PSTN) using cellular technology. The indicator includes two types of subscriptions: postpaid subscriptions and active prepaid accounts. Active prepaid accounts are those that have been used during the last 3 months. The indicator applies to all mobile cellular subscriptions that offer voice communications. However, it excludes subscriptions via data cards or USB modems, subscriptions to public mobile data services, private trunked mobile radio, telepoint, radio paging, and telemetry services.	No.	World Bank (2023)
Secure Internet servers (per 1 million people)	**Servers**	The number of distinct, publicly-trusted TLS/SSL certificates found in the Netcraft Secure Server Survey	No.	World Bank (2023)
Fixed broadband subscriptions (per 100 people)	**Broadband**	Fixed broadband subscriptions encompass the fixed subscriptions that provide high-speed access to the public Internet through a TCP/IP connection at downstream speeds equal to or greater than 256 kbit/s. This includes cable modem, DSL, fiber-to-the-home/building, other fixed (wired)-broadband subscriptions, satellite broadband, and terrestrial fixed wireless broadband. The total number of fixed broadband subscriptions is measured regardless of the method of payment, and it includes fixed WiMAX and any other fixed wireless technologies. This count comprises both residential subscriptions and subscriptions for organizations. However, it excludes subscriptions that have access to data communications, including the Internet, via mobile-cellular networks.	No.	World Bank (2023)
Fixed telephone subscriptions (per 100 people)	**Tel**	Fixed telephone subscriptions include active analogue lines, voice-over-IP (VoIP) subscriptions,	No.	World Bank (2023)

(*continued on next page*)

Table 1 (*continued*)

Variables	Code	Description	Unit/ Scale	Source
		fixed wireless local loop, ISDN voice-channel equivalents, and fixed public payphones.		
Control variables				
Unemployment	**Unempl**	The unemployment rate is the percentage of people in the labour force who are actively seeking employment but unable to find work.	%	World Bank (2023)
Urban population (% of total population)	**Urban**	Urban population refers to individuals residing in urban areas, as defined by national statistical offices. The data are collected and smoothed by the United Nations Population Division.	No.	World Bank (2023)
Moderating variable				
Gender Inequality Index	**GenIneql**	The Gender Inequality Index (GII) is a tool for identifying gender disparities in health, empowerment, and the labour market. A higher value suggests poor performance. This composite index reflects the inequality in achievements between men and women in three dimensions: reproductive health, empowerment, and the labour market.	Value	UNDP (2023)

Table 2
Descriptive statistics of variables.

Variable	Obs	Mean	Std. dev.	Min	Max
Happy	2042	5.4874	1.1191	2.179	8.0189
PROSP	2505	56.7371	13.1267	29.4343	84.2688
Internet	2871	40.5547	30.7116	0	100
Mobile	3063	91.5301	46.2248	0	420.8531
Servers	1993	4233.835	17,594.28	0	277,330.6
Broadband	2884	10.7379	12.4737	0	47.4984
Tel	3033	16.9423	16.4912	0	69.3246
GenIneqI	2813	0.3798	0.1953	0.013	0.82
Unempl	3041	7.8494	5.8048	0.1	37.32
Urban	3111	57.6154	22.9415	9.375	100

The definition of well-being has been approached from numerous perspectives, with two primary paradigms garnering widespread usage - *subjective well-being* and *objective well-being* (Maiti & Awasthi, 2020; Joshanloo et al., 2019). These constructs are not mutually exclusive and have both been used to examine different aspects of well-being. The *subjective perspective* concerns individuals' self-reported experiences and evaluations of their life satisfaction, while the *objective perspective* considers more external factors, such as personal growth, income or richness, self-realization, health status and tangible goods (Maiti & Awasthi, 2020).

According to Joshanloo et al. (2019), the *subjective perspective* on well-being involves evaluating one's life based on cognitive and affective factors. This perspective is typically measured using subjective indicators, as noted by Kashdan et al. (2008). However, Delle Fave (2016) contends there is no consensus on which subjective variables are the most reliable well-being indicators. Ganju et al. (2016) have argued that the term "subjective well-being" is commonly referred to as "happiness." Subjective well-being is a concept that seeks to encapsulate an individual's holistic evaluation of their life, considering both positive and negative elements. This assessment involves cognitive evaluations, encompassing levels of interest and engagement, in addition to emotional reactions towards events such as joy and sadness (Ganjnu et al., 2016). The *objective well-being perspective* focuses on reaching one's full potential, accomplishing personal goals, maintaining vital functions, and fulfilling the purpose of life. Generally, emotional elements are disregarded in this viewpoint. (Maiti & Awasthi, 2020; Joshanloo et al., 2019; Huta & Waterman, 2014).

Although they may differ, both perspectives are essential for comprehending the multifaceted nature of well-being. However, most previous global studies on well-being have mainly concentrated on indicators of subjective well-being, such as life satisfaction (Diener & Seligman, 2018), while indicators of objective well-being have seldom been used in global well-being studies (Joshanloo et al., 2019). Therefore, in developing this study, we have decided to utilize a subjective well-being indicator as the primary analysis (dependent variable). However, to ensure the robustness of our findings, we plan to replace the dependent variable with another indicator, such as prosperity, which would be more suitable for measuring objective well-being. The purpose of this is to provide a more comprehensive analysis of the multifaceted nature of well-being.

For the purpose of evaluating the impact of adopting ICTs on subjective well-being, the life ladder index was chosen as the primary measure of subjective well-being. This index is sourced from the World Happiness Database and is based on a survey in which participants rate their life happiness on a scale of 0 to 10. A rating of 0 indicates the worst possible perception of life satisfaction, while a rating of 10 represents the best. This index has been widely used in previous studies related to subjective well-being and life satisfaction (e.g. Kouladoum et al., 2023; Ketu, 2023; Wang & Sohail, 2022; Mignamissi & Malah Kuete, 2021; Li and An, 2020; Sulemana & James, 2019; Ganju et al., 2016), which supports its selection for this study.

To ensure the robustness of our analysis, we deemed it necessary to substitute the dependent variable employed in the main analysis with another relevant variable that pertains to well-being. In this instance, however, our aim was to capture the objective perspective of well-being. Therefore, we chose to use the Legatum Prosperity Index, which is a tool commonly used to evaluate countries based on how well their residents can economically and socially thrive. This index considers a wide range of factors that contribute to a truly prosperous life, surpassing traditional economic measures like GDP per capita. Also, the index score provides a comprehensive assessment of a country's level of prosperity and is widely regarded as one of the most comprehensive measures of well-being and human progress (Legatum Institute, 2023). This decision was based on previous research that supported the effectiveness of the Legatum Prosperity Index as a reliable measure of well-being, as it is considered to be a more holistic and comprehensive indicator

Table 3
Correlation matrix for all variables used in the study.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Happy (1)	1									
PROSP (2)	0.8105	1								
Internet (3)	0.7416	0.8587	1							
Mobile (4)	0.4985	0.5488	0.6041	1						
Servers (5)	0.3298	0.396	0.3487	0.1114	1					
Broadband (6)	0.7141	0.8906	0.8642	0.4134	0.4317	1				
Tel (7)	0.6242	0.7782	0.7235	0.387	0.1895	0.8321	1			
GenIneqI (8)	-0.7095	-0.8908	-0.8522	-0.5477	-0.3431	-0.8755	-0.7848	1		
Unempl (9)	-0.1582	0.0583	0.1019	0.1064	-0.0903	0.0566	0.1341	-0.1547	1	
Urban (10)	0.6886	0.6959	0.7573	0.5651	0.2304	0.6381	0.617	-0.6156	0.1136	1

(Joshanloo et al., 2019; Otoiu et al., 2014).

Independent variables

This study aims to examine the impact of ICT adoption on subjective well-being. Therefore, our set of independent variables includes proxies that are frequently used for measuring ICT, such as the percentage of individuals using the Internet, mobile cellular subscriptions (per 100 people), secure Internet servers (per 1 million people), fixed broadband subscriptions (per 100 people) and fixed telephone subscriptions (per 100 people). All the data has been sourced from the World Bank Development Indicators. In choosing the independent variables related to the use of Internet services, we were influenced by previous studies (e.g. Wang & Sohail, 2022; Bianchi, 2021; Zhang et al., 2020; Richmond & Triplett, 2018; Nie et al., 2017; Ganju et al., 2016) that have highlighted the significant impact of Internet services in enhancing the well-being of different consumer categories. Accessing Internet services can help reduce social inequality by empowering previously voiceless citizens to demand their rights (Ganju et al., 2016). Furthermore, Lu & Kandilov (2021) argued that individuals with lower levels of subjective well-being may benefit more from using mobile internet services. The impact of ICT adoption on well-being can also be examined by considering the use of mobile phones and landline telephones, as highlighted by other previous studies in this field (Nie et al., 2021; Richmond and Triplett, 2018; Ganju et al., 2016) or fixed broadband subscriptions (Paul & Dutta, 2023; Asongu & Odhiambo, 2019; Tchamyou et al., 2019; Richmond & Triplett, 2018). It is widely acknowledged that mobile phones are the most popular ICT tool globally, as noted by Paul and Dutta (2023). For instance, Ganju et al. (2016) found that developing countries improve their well-being mainly through the use of mobile phones, while developed countries improve their well-being through any ICT system, such as fixed-line telephones and the Internet. However, it is crucial to analyse how gender relationships are connected with the utilization of various ICTs tools as this can affect one's personal well-being.

Control variables

The first control variable selected for our study refers to unemployment, as it has been found to have a significant impact on reducing happiness, according to many authors (see for instance Ndoya et al., 2024; Văidean & Achim, 2022; Li & An, 2020; Maiti and Awasthi, 2020). Higher unemployment rates often lead to greater economic and financial uncertainty, which can heighten psychological distress and further deteriorate an individual's mental well-being. There is substantial evidence demonstrating that unemployment significantly negatively impacts life satisfaction. This decline is largely attributed to individuals' fears of job loss, which affect their happiness and overall well-being, leading to mental health issues such as depression and anxiety (Danish & Nawaz, 2022; Văidean & Achim, 2022; Li & An, 2020; Maiti & Awasthi, 2020; Asadullah et al., 2018; Altindag & Xu, 2017; Otoiu et al., 2014; Dolan et al., 2008). The second control variable chosen for our study pertains to the urban population. This decision was based on previous research which suggests that policies aimed at reducing differences between rural and urban areas are likely to enhance overall well-being (Janz et al., 2023; Văidean & Achim, 2022; Wang & Sohail, 2022; Joshanloo et al., 2019; Asadullah et al., 2018; Jiang et al., 2012; Wang & VanderWeele, 2011; Smyth et al., 2010; Knight & Gunatilaka, 2010).

Moderating variable – gender inequality

In many studies aimed at analysing the factors that affect subjective well-being, gender is often included as a control variable. This is based on the assumption that the well-being perception of different genders varies, as argued by previous researchers (Danish & Nawaz, 2022; Nie et al., 2021; Yan & Wen, 2020; Ciziceno & Travaglino, 2019; Tay et al., 2014; Jiang et al., 2012). However, other studies suggest that policies aimed at reducing gender inequalities can significantly improve well-being, as highlighted by Asadullah et al. (2018). Our study is aimed at investigating whether gender inequality has a moderating effect on the relationship between information and communication technologies (ICTs) and well-being. For this purpose, we are considering the Gender Inequality Index (*GenIneql*) as a moderating variable, which is computed by the United Nations Development Programme (UNDP, 2023). The Gender Inequality Index is a tool that identifies gender disparities in health, empowerment, and the labour market. A higher value of the index suggests poorer performance in these dimensions. This composite index reflects the inequality in achievements between men and women in three dimensions: reproductive health, empowerment, and the labour market. Our decision to use this index was inspired by previous studies related to the interplay between gender, well-being and the ICT field (e.g. Mouronte-López & Ceres, 2021; Audette et al., 2019; Batz-Barbarich et al., 2018; Gray et al., 2017).

Table 2 presents our extensive international sample of countries over a broad time span, showcasing a multivariate non-graphical exploratory data analysis of the variables used in this study. Notably, several countries with high life satisfaction (Happy) scores, such as Canada, Israel, Denmark, Luxembourg, and Norway, have a relatively low Gender Inequality Index, reflecting strong performance in this regard. In contrast, Brazil and Venezuela exhibit elevated life satisfaction levels despite their Gender Inequality Indexes being above the average, indicating less favourable performance. On the other end of the spectrum, countries such as Burundi, Liberia, South Sudan, Togo, and Zimbabwe display the lowest life satisfaction scores, all linked to poor gender inequality outcomes. Additionally, while South Africa and Serbia boast impressive ICT indicators, their life satisfaction (Happy) ratings remain below average throughout the studied period, with South Africa showing poorer gender equality compared to the average and Serbia demonstrating significantly better performance. This suggests a compelling opportunity to explore the moderating effect of gender inequality on the relationship between ICT and life satisfaction. For further insight, a multivariate graphical exploratory data analysis can be found in Appendix 1. Appendix 1 also includes a detailed list of the countries.

Empirical model

We intend to examine how adopting information and communication technologies (ICTs) affects well-being. We also study how gender inequality influences this relationship. When two predictor variables (ICTs proxies, i.e. *Internet, Mobile, Servers, Broadband*, and *Tel*) and Gender Inequality Index (*GenIneqI*) are involved, the presence of interaction signifies that the impact of one predictor variable on the response variable (life satisfaction as Happy for the main analysis) differs at different values of the other predictor variable. We test this by adding a term to the model where the two predictor variables are multiplied. We have added a gender inequality proxy and the interaction term between that gender inequality proxy and our technology proxies to our baseline models. We will estimate the individual impact of technologies on well-being and then the effect of technologies on well-being, moderated by the Gender Inequality Index, while also considering some control variables (as shown in Eq. 1):

$$\text{Happy}_{it} = \beta_0 + \beta_1 \text{ICT}_{it} + \beta_2 \text{GenIneqI}_{it} + \beta_3 \text{ICT}_{it} * \text{GenIneqI}_{it} + \beta_4 \text{Unempl}_{it} + \beta_5 \text{Urban}_{it} + \varepsilon_{it} \quad (1)$$

Where:

Happy_{it} – proxy for the subjective well-being of country i in year t;
β_o – constant;
β_{1-5} – estimated coefficients of independent variables related to ICTs adoption;
ICT_{it} – proxy for the information and communication technologies of country i in year t, whose vector includes, on turn, *Internet use-Internet*$_{it}$, *Mobile penetration-Mobile*$_{it}$, *Servers implementation-Servers*$_{it}$, *Broadband connectivity-Broadband*$_{it}$ and *Telephone lines-Tel*$_{it}$;
GenIneqI_{it} – Gender Inequality Index for country i in year t;
Unempl_{it} – unemployment rates of country i in year t;
Urban_{i} – urbanisation rate of country i in year t;
ε_{it} - the residual.

Regarding our *a priori* expectations, well-being is positively impacted by ICT adoption ($\beta_1 > 0$) and hindered by gender inequalities ($\beta_2 < 0$). β_3 varies when the interaction of the Gender Inequality Index on ICT proxies boosts or alters the impact of ICTs on well-being. Therefore, the *total* effect of technologies on well-being given gender inequality moderation is computed as:

$$\frac{\delta Happy}{\delta ICT} = \beta_1 + \beta_3 \ \text{GenIneqI}_{it} \quad (2)$$

If the sign of β1 is the same as the sign of β3, it implies that the interaction term strengthens the impact of ICTs on well-being in the regression analysis. However, if the sign of β1 is different from β3, it suggests that introducing the interaction term *alters* the impact of ICTs on well-being.

Estimation techniques

Our paper employs multiple regression analysis, specifically the combinatorial approach, as its primary multivariate data analysis technique. Modelling assumptions are checked, and transformations of variables are applied where needed. In addition to the Pooled OLS method, our study also utilises fixed effects modelling to provide a better assessment of the impact of ICTs on well-being, moderated by gender inequality. Essentially, a positive (or negative) coefficient of the interaction term (β3) indicates a complementary (or substitutable) relationship between ICTs and gender inequality. In other words, the gender inequality index increases (or decreases) the effect of ICTs on well-being. We also perform robustness checks and use prosperity as another dependent variable suitable for measuring well-being at the country level and then add another control variable. We have chosen to use multiple regression analysis, specifically the combinatorial approach, which enables us to evaluate the combined effects of several independent variables—such as ICT and gender inequality—on well-being. This comprehensive analysis captures the intricate interactions and dependencies among these variables, thereby enhancing our study insights. By applying Pooled OLS and fixed-effects modelling, we effectively address potential biases arising from unobserved heterogeneity across countries. Fixed-effects models isolate time-invariant characteristics, thereby providing more accurate estimates of the impacts of ICT and gender inequality on well-being from both subjective and objective perspectives. Additionally, including gender inequality as a moderating factor underscores our commitment to exploring nuanced dynamics. This analysis highlights how ICT's influence on well-being varies based on gender inequality levels, enhancing the relevance and actionability of our findings.

Empirical results and discussions

Results of the main analysis

Our main findings are contained in Table 4a, 4b and Fig. 1, where we show how the impact of ICTs on well-being is influenced by gender inequality through *GenIneqI*. Table 4a presents the coefficient estimates for Eq. 1, first without considering the terms with *GenIneqI* (Models 1–5), and then including the interaction term of *GenIneqI* with ICT proxies, as well as *GenIneqI* on its own (Models 1′-5′). For normality purposes, the logarithmic transformation is applied to *Servers, Broadband* and *Tel*. The variables have been tested for heteroscedasticity. Table 4b contains the estimated marginal effects for gender inequality moderation of the ICT effect on well-being, where significant. Additionally, we illustrate the average marginal effects of several ICT proxies with their 95% confidence intervals graphically in Fig. 1. This representation shows the effect of ICT proxies on subjective well-being, conditioned by the gender inequality proxy. We observe nonlinearities in the estimated coefficients' magnitude, sign, and significance, which may become non-significant at specific values of the Gender Inequality Index.

According to Table 4a, the positive impact of ICT proxies (such as *Internet, Mobile*, and the logarithm of other ICT proxies, for normality purposes: *LogServers, LogBroadband, LogTel*) on well-being (subjective perspective) is not limited to the estimated coefficients for ICT proxies from models (1), (2), (3), (4), and (5). The estimated coefficients for ICT proxies in these models are 0.016, 0.0041, 0.1456, 0.1868, and 0.2839, respectively, and are all significant at a 1% threshold. The effect of ICT proxies on well-being also depends on the values of the estimated coefficients for the interaction terms (between ICTs proxies and *GenIneqI*) and *GenIneqI* in models (1′), (2′), (3′), (4′), and (5′).

Model (1′) and its base Eq. (1) may be rewritten as follows:

Happy_{it} = 0.0064*Internet_{it} – 1.9448*GenIneqI_{it} – 0.0081*Internet_{it}*GenIneqI_{it} – 0.0526*Unempl_{it} + 0.0209*Urban_{it} + ε_{it} (model (1′))

Because the estimated coefficient for the *Internet* (0.0064) and the estimated coefficient for *Internet* ***x*** *GenIneqI* (-0.0081) are both significant but have different signs, the moderation effect of *GenIneqI* manifests itself by altering the Internet's impact upon *Happy* when *GenIneqI* is included within the regression.

A similar interpretation holds for models (4′) and (5′) in Table 4a, which may be rewritten without control variables as:

Happy_{it} = 0.1216*LogBroadband_{it} – 1.9693*GenIneqI_{it} – 0.1259*LogBroadband_{it}*GenIneqI_{it} (Model (4′))
Happy_{it} = 0.1847*LogTel_{it} – 1.7542*GenIneqI_{it} – 0.1101*LogTel_{it}*GenIneqI_{it} (Model (5′))

Table 4a
The effect of ICTs on subjective well-being, without and with nonlinearities.

Happy	(1)	(1′) 1 with moderating effect	(2)	(2′) 2 with moderating effect	(3)	(3′) 3 with moderating effect	(4)	(4′) 4 with moderating effect	(5)	(5′) 5 with moderating effect
Internet	0.016***	0.0064***								
GenIneqI		-1.9448***								
GenIneqI *x* Internet		-0.0081***								
Mobile			0.0041***	-0.0028***						
GenIneqI				-3.4747***						
GenIneqI *x* Mobile				0.0077***						
LogServers					0.1456***	0.0624***				
GenIneqI						-2.1096***				
GenIneqI *x* LogServers						-0.0447				
LogBroadband							0.1868***	0.1216***		
GenIneqI								-1.9693***		
GenIneqI *x* LogBroadband								-0.1259***		
LogTel									0.2839***	0.1847***
GenIneqI										-1.7542***
GenIneqI *x* LogTel										-0.1101*
Unempl	-0.0446***	-0.0526***	-0.0467***	-0.0546***	-0.0463***	-0.0541***	-0.0513***	-0.0541***	-0.0528***	-0.0556***
Urban	0.0202***	0.0209***	0.0318***	0.0214***	0.0218***	0.0196***	0.0212***	0.0198***	0.0208***	0.0186***
const	3.8647***	5.1018***	3.4866***	5.8764***	3.8226***	5.1881***	4.3895***	5.2608***	4.0194***	5.0641***
R^2	0.6075	0.6711	0.5248	0.6670	0.6204	0.688	0.5957	0.6657	0.6038	0.6726
Adj R^2	0.6068	0.6703	0.5241	0.6661	0.6196	0.6869	0.5951	0.6648	0.6032	0.6717
No obs	1900	1875	1997	1970	1454	1438	1921	1896	1970	1943

Note: *<0.10, **<0.05, and ***<0.01

Because the estimated coefficient for the ICT proxies (0.1216 for *LogBroadband* and, respectively, 0.1847 for *LogTel*) and the estimated coefficient for the interaction term between the ICT proxies and *GenIneqI* (-0.1259 and -0.1101) have opposed signs, the moderation effect of *GenIneqI* manifests itself by diminishing the impact of ICTs upon *Happy* when *GenIneqI* is included within the regression.

Model (2′) is an interesting case as it includes an interaction term that changes the sign of the estimated coefficient for *Mobile*, making it negative (-0.0028). However, the interpretation of the interaction term remains the same as its sign is positive (0.0077). This suggests that the impact of ICT proxied by *Mobile* is reduced when gender inequality is included in the analysis. According to Model (3′), there is no moderation effect of *GenIneqI* on the estimation of the effect of ICT proxied by *LogServers* on *Happy* since the -0.0447 coefficient for the interaction term is not significant.

Table 4b and Fig. 1 provide additional information to Table 4a for the models where nonlinearities are significant, such as models (1′), (2′) and (4′). Specifically, the data covers our gender inequality index, ranging from 0.013 (low inequality between women and men) to 0.82 (high inequality between women and men). The data is presented at intervals of one standard deviation. For each value of *GenIneqI*, at a pace of 0.1953, Table 4b shows the marginal effect calculation, their standard errors, z-scores and p-values. Fig. 1 depicts the average marginal effects of ICT proxies on well-being (in blue) with 95% confidence intervals (in red) for each value of *GenIneqI*. These values are estimated from Table 4b and are shown at the corresponding points on the Gender Inequality Index.

The results for marginal effects from Model (1′) presented in Table 4b and Fig. 1 suggest that when *GenIneqI* (measuring gender inequalities within countries) changes from its minimum to maximum values, the impact of Internet use as a proxy for ICT upon Happy as a proxy for well-being is nonlinear in terms of magnitude. In other words, the positive impact of *Internet* on well-being slowly decreases and even becomes insignificant for extreme levels of inequality (above *GenIneqI* = 0.7942). As gender inequality increases (*GenIneqI* increases), the positive impact of *Internet* on well-being decreases.

According to the results of Model (2′) disclosed in Table 4b and Fig. 1, there is a point between *GenIneqI* values of 0.013 and 0.2083 where the impact of *Mobile* on *Happy* becomes significant and is predicted to be positive. However, the impact slightly decreases as *GenIneqI* increases and exceeds its average value. This means that as gender inequalities become higher, the impact of *Mobile* as a proxy for information and communication technology on Happy as a proxy for well-being remains positive but decreases.

The Model (4′) depicted in Table 4b and Fig. 1 includes significance, sign, and magnitude nonlinearities. Based on the results for model (4′) in Table 4b, we can conclude that for *GenIneqI* values between 0.7942 and 0.82, the estimated impact of *LogBroadband* on *Happy* becomes significant once again, and even negative, although it was not significant in the vicinity of *GenIneqI* = 0.5989. As gender inequality increases, the impact of ICT (proxied by *LogBroadband*) on well-being proxied by *Happy* decreases. However, for low gender inequalities, the impact of *LogBroadband* on *Happy* is positive. Lower gender inequality indexes (up to *GenIneqI*=0.4036) positively affect well-being through this ICT proxy, with a more pronounced magnitude for lower gender inequality indexes. Therefore, lower gender inequality between men and women has a more positive direct effect on ICT proxies on well-being, as observed in other models. Finally, Model (5′) did not yield significant probabilities for any *GenIneqI* values, so its marginal effects were not considered.

Robustness analysis

To enhance the reliability of our main findings, we conducted several robustness checks, which involved the following aspects, in sequence: (1) we utilized an alternative measure for our dependent variable, namely the Legatum Prosperity Index (*PROSP*), rather than *Happy*, to

Table 4b
Marginal effects results for gender inequality moderation of the ICTs effect on subjective well-being.

Model (1′)					Model (2′)					Model (4′)				
Internet at	dy/dx	Std. error	Z	P>|z|	*Mobile* at	dy/dx	Std. error	Z	P>|z|	*LogBroadband* at	dy/dx	Std. error	Z	P>|z|
GenIneqI = 0.013	0.0048	0.0015	3.24	0.001	GenIneqI = 0.013	0.00125	0.0011	1.16	0.244	GenIneqI = 0.013	0.1211	0.0311	3.9	0
GenIneqI = 0.2083	0.0044	0.0011	4.14	0	GenIneqI = 0.2083	0.00124	0.0007	1.76	0.079	GenIneqI = 0.2083	0.0815	0.0217	3.75	0
GenIneqI = 0.4036	0.004	0.0011	3.8	0	GenIneqI = 0.4036	0.00122	0.0004	2.47	0.014	GenIneqI = 0.4036	0.042	0.0143	2.93	0.003
GenIneqI = 0.5989	0.0035	0.0014	2.44	0.015	GenIneqI = 0.5989	0.00121	0.0006	1.9	0.057	GenIneqI = 0.5989	0.0024	0.0129	0.19	0.848
GenIneqI = 0.7942	0.0031	0.0021	1.52	0.129	GenIneqI = 0.7942	0.00119	0.0009	1.21	0.226	GenIneqI = 0.7942	-0.0371	0.0189	-1.96	0.05
GenIneqI =0.82	0.0031	0.0021	1.43	0.152	GenIneqI =0.82	0.00119	0.001	1.15	0.25	GenIneqI =0.82	-0.0423	0.0199	-2.12	0.034

gauge, this time, the objective perspective of well-being; and (2) we introduced an additional control variable to Eq. 1, namely population growth.

(1) First, as an alternative proxy for measuring well-being, we chose the Legatum Prosperity Index (PROSP) to capture the impact of ICTs on the objective perspective of well-being. The Legatum Prosperity Index is a comprehensive assessment of a country's level of prosperity and is widely considered to be one of the most comprehensive measures of well-being and human progress available (Legatum Institute, 2023). Our decision to use this index was based on previous research showing it to be a reliable measure of well-being (Otoiu et al., 2014). In this case, the Eq. 1 was rewritten as follows:

$$\mathrm{PROSP}_{it} = \beta_0 + \beta_1 \mathrm{ICT}_{it} + \beta_2 \mathrm{GenIneqI}_{it} + \beta_3 \mathrm{ICT}_{it} \times \mathrm{GenIneqI}_{it} + \beta_4 \mathrm{Unempl}_{it} + \beta_5 \mathrm{Urban}_{it} + \varepsilon_{it} \quad (3)$$

The following estimates are summarized in Table 5a, 5b, and Fig. 2. Table 5a examines the impact of various ICTs indicators on the Legatum Prosperity Index, which is another reliable indicator of prosperity and well-being, in Models (1)-(5). Models (1′) - (5′) include the Gender Inequality Index and its interaction with various ICT indicators, as well as previously validated control variables and ICTs proxies. Except for Model (2′), we obtain robust validation of the impact of ICTs on *PROSP*, moderated by existing gender inequalities: the beneficial impact of technologies on prosperity is reduced by existing gender inequalities. Therefore, the estimated coefficients of ICT indicators in Models (1′), (3′), (4′), and (5′) are positive and significant, while the estimated coefficient for the interaction between ICTs and Gender Inequality is negative and significant.

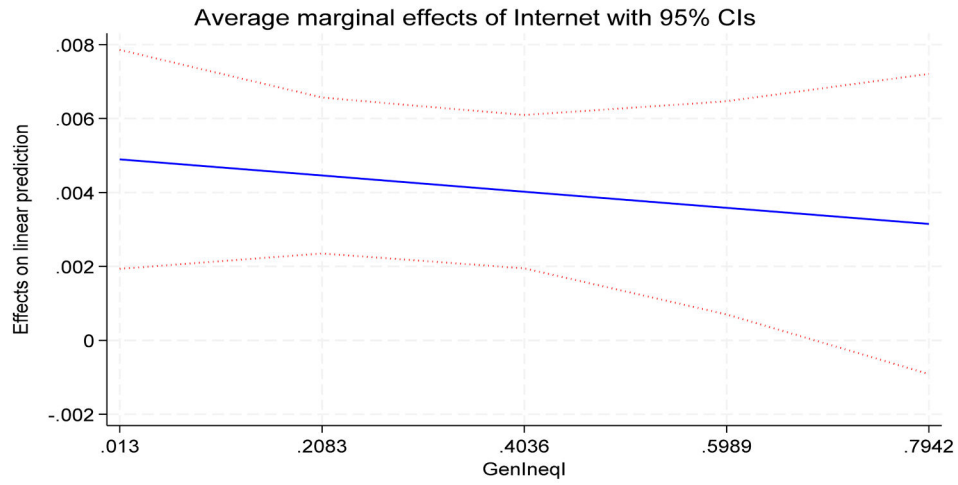
Table 5b displays the marginal effects of ICTs on prosperity at different levels of the Gender Inequality Index. The positive impact of ICTs on *PROSP* is moderated by gender inequality and is hampered as gender inequality increases. This effect is significant for most values of gender inequality. In Model (1′), we see a strong decrease in the positive impact of ICTs on prosperity, from 0.16 at the minimum gender inequality index value to 0.0344 at a *GenIneqI* of 0.5989. Beyond this *GenIneqI* value, the impact becomes insignificant. In Model (2′), the estimated coefficient of *Mobile* was not significant, so no further calculations were made. In Model (3′), we observe that as the *GenIneqI* increases from its minimum to maximum values, the positive impact of ICTs measured as *LogServers*, on well-being measured through prosperity decreases from 1.7415 to 0.5517, which is more than three times, and it is consistently significant. Models (4′) and (5′) are particularly interesting because they exhibit nonlinearities in magnitude, significance, and sign, as depicted graphically in Fig. 2. In Model (4′), the positive effects of *LogBroadband* on PROSP are reduced in the presence of an increase in *GenIneqI* from its minimum values up to 0.5989. Then, the effect of *LogBroadband* becomes insignificant (at *GenIneqI* of 0.7942), only to become negative (-0.0744) at the maximum *GenIneqI* value of 0.82. A similar pattern is reflected by Model (5′): the positive effect of *LogTel* on PROSP decreases from 3.3613 (at *GenIneqI* = 0.013) to 0.7123 (at *GenIneqI* = 0.5989) in the presence of an increase in *GenIneqI*. The effect then becomes insignificant for a *GenIneqI* of 0.7942 and becomes negative (-0.2873), which is significant at 1% because p =0.065, at the highest values of *GenIneqI* in the vicinity of 0.82. Finally, Fig. 2 clearly illustrates a substitutability relationship between ICTs and gender inequality: the gender inequality index decreases the effect of ICTs upon prosperity as an objective well-being indicator, all trends of the graphs being downwards.

(2) For the second robustness check, one additional control variable was added to Eq. 1. Specifically, population growth (PopGr), which is commonly used as a control variable in previous studies investigating the factors that impact well-being (e.g. Kim et al., 2023; Janz et al., 2023), was included. The results of these estimations are summarized in Table 6, which includes the estimations from Table 4a along with the addition of *PopGr* as a control variable, alongside *Unempl* and *Urban*. It is worth noting that Table 6 supports the direction of impact and significance level estimates from Table 4a, highlighting the moderating effect of gender inequalities in the ICT–life satisfaction nexus, particularly when the growth rate of the population is included as an additional control variable.

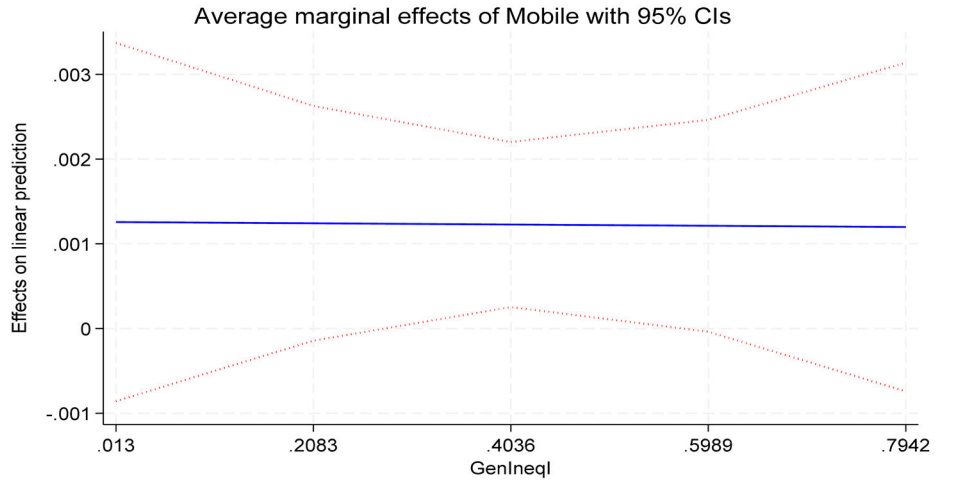
Discussions

This study aimed to explore the impact of different information and communication technologies on well-being while examining the role of gender inequality in moderating this impact. Given the complexity of the concept of well-being, the study considered both subjective and objective perspectives. The main analysis used happiness (life satisfaction) as the dependent variable, which is one of the most commonly used indicators of subjective well-being, while the robustness analysis employed another reliable measure of objective well-being called prosperity. Prosperity mainly reflects the social and economic aspects of well-being from an objective perspective. The findings from both the main analysis and robustness checks indicate that the positive impact of Information and Communication Technology (ICT) on well-being is significantly influenced by gender inequality. Specifically, the more the differential treatment of men and women is reduced, the greater the positive effect of ICT on well-being. This suggests that technological advancements alone are not enough to enhance quality of life; rather, they must be paired with structural efforts to reduce gender disparities. This presents a significant challenge for policymakers, who are tasked

Average marginal effects of *Internet* with 95% confidence intervals - **Model (1')**



Average marginal effects of *Mobile* with 95% confidence intervals - **Model (2')**



Average marginal effects of *LogBroadband* with 95% confidence intervals - **Model (4')**

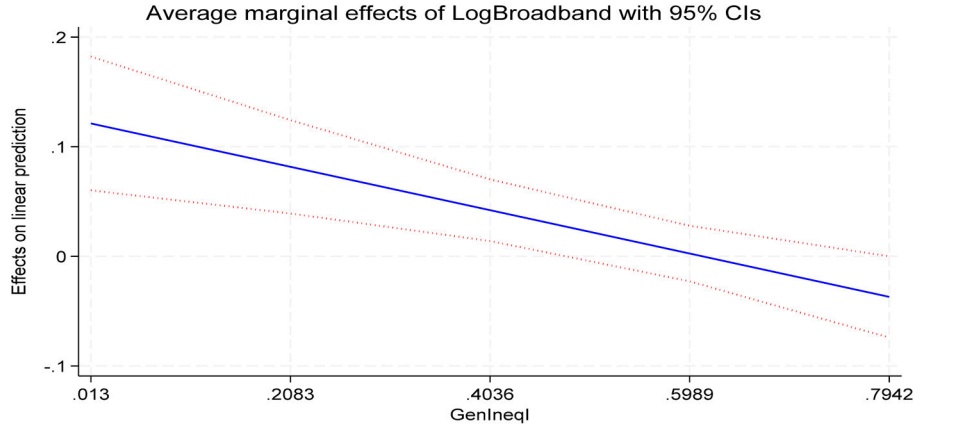


Fig. 1. Average marginal effects of *Internet, Mobile* and *LogBroadband*.

Table 5a
The effect of ICTs on objective well-being without and with nonlinearities.

PROSP	(1)	(1') 1 with moderating effect	(2)	(2') 2 with moderating effect	(3)	(3') 3 with moderating effect	(4)	(4') 4 with moderating effect	(5)	(5') 5 with moderating effect
Internet	0.3051***	0.1628***								
GenIneql		-29.9353***								
GenIneql x Internet		-0.2143***								
Mobile			0.111***	0.0015						
GenIneql				-51.6043***						
GenIneql x Mobile				0.0395**						
LogServers					2.716***	1.7607***				
GenIneql						-28.1456***				
GenIneql x LogServers						-1.4744***				
LogBroadband							3.2119***	3.5584***		
GenIneql								-28.7949***		
GenIneql x LogBroadband								-4.5743***		
LogTel									4.1703***	3.4201***
GenIneql										-30.3183***
GenIneql x LogTel										-4.5212***
Unempl	-0.0904***	-0.099***	-0.1967***	-0.1862***	-0.1508***	-0.1315***	-0.2455***	-0.1612***	-0.2686***	-0.1774***
Urban	0.1026***	0.0995***	0.2842***	0.1142***	0.1447***	0.0888***	0.1433***	0.0845***	0.1785***	0.0982***
const	38.484***	58.4908***	30.7057***	69.5696***	37.8271***	57.1728***	48.0057***	60.7955***	40.5428***	59.458***
R^2	0.7345	0.8439	0.5593	0.8205	0.7629	0.8573	0.7004	0.8478	0.6541	0.826
Adj R^2	0.7341	0.8435	0.5588	0.8201	0.7625	0.8569	0.7001	0.8475	0.6537	0.8256
No obs	2287	2204	2436	2337	1781	1723	2333	2241	2384	2286

Note: *<0.10, **<0.05, and ***<0.01

with the effective integration of technological advancements alongside necessary social reforms. They are confronted with a critical question: Can technological advancements alone enhance overall well-being, or are concurrent social reforms essential to address existing disparities?

The independent variables used in this study to measure ICT include proxies that are frequently used, such as the percentage of individuals using the Internet - *Internet*, mobile cellular subscriptions (per 100 people) - *Mobile*, secure Internet servers (per 1 million people) - *Servers*, fixed broadband subscriptions (per 100 people) - *Broadband*, and fixed telephone subscriptions (per 100 people) – *Tel*. The general finding from both the main and robustness analysis is that there is a positive correlation between the direct impact of ICTs proxies on well-being and the reduction of gender inequality. Specifically, the greater the reduction in the differential treatment of men and women, the more pronounced the positive impact of ICT proxies on well-being.

Going in-depth into the results of the main analysis, when well-being was proxied by a subjective indicator, namely, happiness, it can be noted that: (1) the impact of *Internet* use on happiness is non-linear in terms of magnitude, and its positive impact on subjective well-being slowly decreases and even becomes insignificant for extreme levels of gender inequality; (2) the impact of *Broadband* and *Tel* on subjective well-being is positive and with a more pronounced magnitude for lower gender inequalities; (3) regarding the *Mobile*, here it is an interesting situation because when gender inequalities are included in the analysis, the impact of *Mobile* is reduced; (4) finally, in what regard the nexus *Servers* – subjective well-being, the main analysis revealed no moderation effect of gender inequality.

With respect to the robustness analysis, the findings revealed that when measuring objective well-being through economic and social prosperity as the dependent variable of well-being, ICTs (*Internet, Tel, Servers,* and *Broadband*) had a definite positive impact on well-being (measured by PROSP). However, this positive effect was observed to decrease as gender inequality increased. On the other hand, the study did not confirm the impact of *Mobile* on objective well-being when measured by economic and social prosperity.

Comparing our study's findings with existing literature can be challenging since, to our knowledge, we are the first to examine the impact of gender inequality as a moderator on the relationship between Information and Communication Technologies (ICTs) and well-being (measured from both subjective and objective perspectives). Our research, however, echoes previous studies that suggest women often encounter obstacles in accessing various ICT tools, which can ultimately impact their opportunities and well-being in modern society. Noteworthy research in this area includes Rahman et al. (2023), Lechman & Popowska (2022), Bosch et al. (2021), and Palomares-Ruiz et al. (2021), all of which emphasize the importance of addressing this gender inequality in ICT access. Our findings are in line with the previous findings related to the positive impact of Internet use (e.g. Zambianchi, 2023; Wang & Sohail, 2022; Asongu et al., 2021; Castellacci & Schwabe, 2020; Maiti & Awasthi, 2020; Asongu & Odhiambo, 2019; Hall, 2019; Tchamyou et al.; 2019; Castellacci & Tveito, 2018; Richmond & Triplett, 2018), mobile phones (Asongu & Odhiambo, 2019; Asongu et al., 2021; Tchamyou et al., 2019), fixed telephones (Lu & Kandilov, 2021; Ganju et al., 2016), or fixed broadband (Tchamyou et al., 2019; Asongu et al., 2021; Asongu & Odhiambo, 2019) that argued their positive impact on human development and their well-being. However, our findings are not entirely in line with the study of Richmond & Triplett (2018), which suggested that Internet use and mobile phones were associated with a significant reduction in inequality and improvements in well-being, while the effects of broadband did not reach the same level of significance.

Conclusions and policy implications

In this study, we explore the relationship between the adoption of ICTs (Information and Communication Technologies) and well-being

Table 5b
Marginal effects results for gender inequality moderation of the ICT effect on objective well-being.

Model (1′)					Model (3′)				
Internet	dy/dx	Std. error	Z	P>|z|	*LogServers*	dy/dx	Std. error	Z	P>|z|
at					at				
GenIneqI = 0.013	0.16	0.01	15.96	0	GenIneqI = 0.013	1.7415	0.087	20.01	0
GenIneqI = 0.2083	0.1181	0.0077	15.23	0	GenIneqI = 0.2083	1.4536	0.0655	22.18	0
GenIneqI = 0.4036	0.0763	0.0075	10.05	0	GenIneqI = 0.4036	1.1656	0.0627	18.57	0
GenIneqI = 0.5989	0.0344	0.0096	3.58	0	GenIneqI = 0.5989	0.8777	0.0806	10.88	0
GenIneqI = 0.7942	-0.0074	0.0128	-0.58	0.565	GenIneqI = 0.7942	0.5897	0.1095	5.38	0
GenIneqI =0.82	-0.0129	0.0133	-0.97	0.332	GenIneqI =0.82	0.5517	0.1137	4.85	0
Model (4′)					Model (5′)				
LogBroadband	dy/dx	Std. error	Z	P>|z|	*LogTel*	dy/dx	Std. error	Z	P>|z|
at					at				
GenIneqI = 0.013	3.4989	0.158392	22.09	0	GenIneqI = 0.013	3.3613	0.2879	11.67	0
GenIneqI = 0.2083	2.6056	0.114093	22.84	0	GenIneqI = 0.2083	2.4783	0.2055	12.06	0
GenIneqI = 0.4036	1.7122	0.080694	21.22	0	GenIneqI = 0.4036	1.5953	0.1358	11.74	0
GenIneqI = 0.5989	0.8188	0.07464	10.97	0	GenIneqI = 0.5989	0.7123	0.1076	6.62	0
GenIneqI = 0.7942	-0.0744	0.100974	-0.74	0.461	GenIneqI = 0.7942	-0.1706	0.147	-1.16	0.246
GenIneqI =0.82	-0.1925	0.1059	-1.82	0.069	GenIneqI =0.82	-0.2873	0.1555	-1.85	0.065

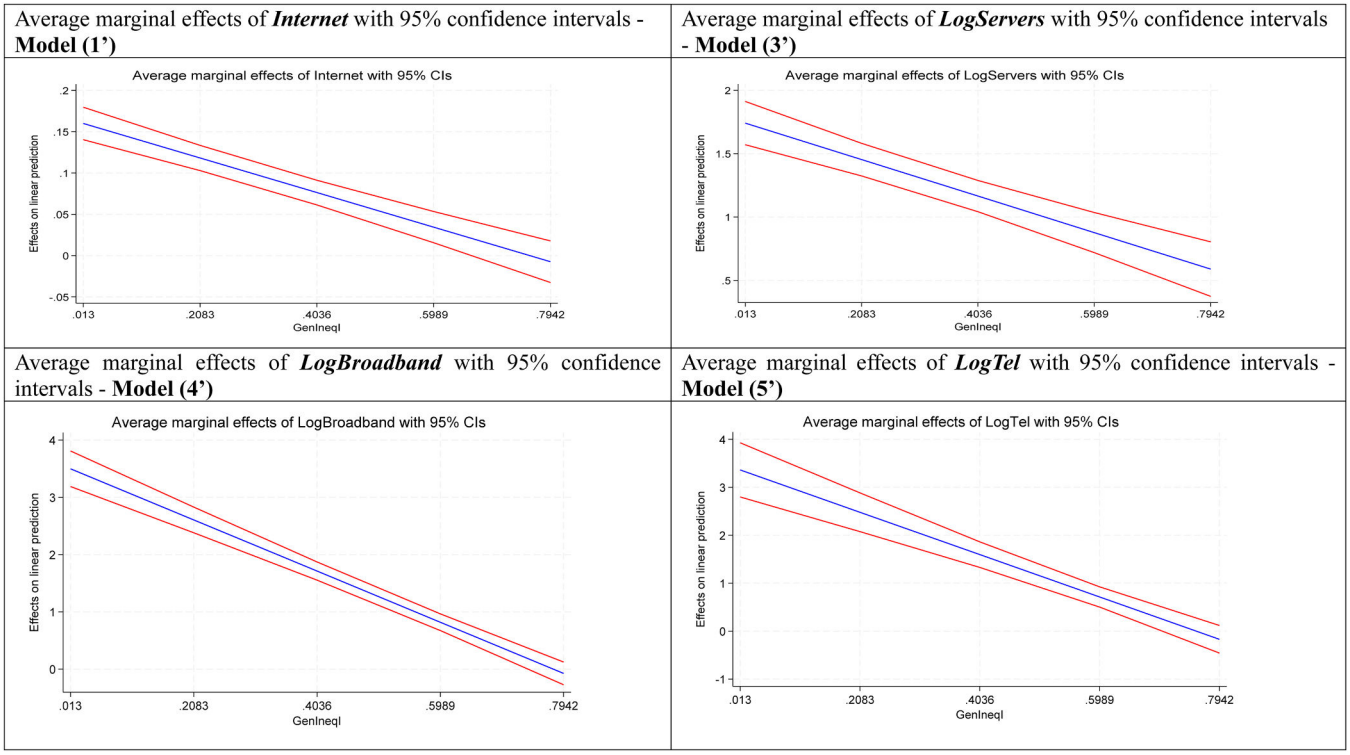


Fig. 2. Average marginal effects of *Internet, Logservers, LogBroadband* and *LogTel.*

while focusing on how gender inequality moderates this relationship. To investigate this, we used data from 185 countries over the period of 2005–2021 while controlling for unemployment and urban population. We acknowledge that well-being is a complex concept that can be measured from both *subjective* and *objective* perspectives. Therefore, we used both subjective and objective indicators to measure well-being. We used happiness (life ladder) as the dependent variable in the main analysis, and prosperity as the dependent variable in the robustness analysis to measure objective well-being. Our main findings indicate that there is a positive correlation between the impact of ICTs proxies on well-being and the reduction of gender inequality. This means that the more significant the reduction in differential treatment between men and women, the more positive the impact of ICT proxies on well-being at the country level. This finding emphasizes the importance of promoting gender equality as a key factor in achieving positive effects of ICTs on well-being. We also discussed the marginal effects of ICTs on well-being at different levels of gender inequality in detail. Our study's findings offer unique perspectives on the role of gender equality in preserving the positive effects of ICTs on well-being measured from both *subjective* and *objective* perspectives. This study extends the theoretical framework on the relationship between ICTs and well-being by incorporating the moderating role of gender inequality, providing a nuanced understanding of how ICTs proxies and gender inequality interact to influence subjective and objective well-being. It is argued that the benefits of ICT adoption on well-being are not uniformly distributed but are contingent on contextual factors, such as gender inequality.

Table 6
The effect of ICTs on subjective well-being, without and with nonlinearities, when *PopGr* is added as a supplementary control variable.

Happy	(1)	(1') 1 with moderating effect	(2)	(2') 2 with moderating effect	(3)	(3') 3 with moderating effect	(4)	(4') 4 with moderating effect	(5)	(5') 5 with moderating effect
Internet	0.0152***	0.0059***								
GenIneqI		-2.1872***								
GenIneqI x Internet		-0.0064**								
Mobile			0.0031***	-0.0031***						
GenIneqI				-3.7981***						
GenIneqI x Mobile				0.0086***						
LogServers					0.1395***	0.0608***				
GenIneqI						-2.3541***				
GenIneqI x LogServers						-0.0294				
LogBroadband							0.1918***	0.1385***		
GenIneqI								-2.1583***		
GenIneqI x LogBroadband								-0.1247***		
LogTel									0.2916***	0.2036***
GenIneqI										-2.0143***
GenIneqI x LogTel										-0.09825
Unempl	-0.0468***	-0.0506***	-0.0528***	-0.0517***	-0.0479***	-0.0518***	-0.0507***	-0.0504***	-0.0521***	-0.0517***
Urban	0.0206***	0.0203***	0.0315***	0.0206***	0.0221***	0.0189***	0.021***	0.0182***	0.0206***	0.0171***
PopGr	-0.0309**	0.0376***	-0.1004***	0.0523***	-0.0264*	0. 0.0471***	0.0121	0.0693***	0.0134	0.0773***
const	3.9322***	5.1652***	3.7792***	5.9486***	3.8824***	5.2315***	4.3785***	5.2877***	3.9947***	5.0774***
R^2	0.6087	0.6726	0.5393	0.6700	0.6212	0.6901	0.5959	0.6706	0.6040	0.6787
Adj R^2	0.6078	0.6716	0.5383	0.6690	0.6201	0.6888	0.5950	0.6695	0.6032	0.6777
No obs	1900	1875	1997	1970	1454	1438	1921	1896	1970	1943

Note: *<0.10, **<0.05, and ***<0.01

More specifically, from the main analysis when the impact of ICTs proxies (such as the use of *Internet, mobile cellular and fixed telephone subscriptions, secure Internet servers*, and *fixed broadband subscriptions*) on well-being (measured from a subjective perspective) the results confirmed that the impact of certain ICTs proxies (such as *Internet, Broadband, Tel* and *Mobile*) on subjective well-being is non-linear in terms of magnitude. Upon a thorough examination of the main analysis results, particularly when well-being is assessed through a subjective indicator—happiness (life satisfaction)—several key points emerge: (1) the relationship between *Internet use* and happiness is non-linear, indicating that the magnitude of its impact varies. Specifically, the positive influence on subjective well-being gradually diminishes, potentially becoming insignificant at extreme levels of gender inequality; (2) the effects of *Broadband and Telecommunication (Tel)* on subjective well-being are distinctly positive, exhibiting a more pronounced impact in scenarios characterised by lower gender inequality; (iii) Interestingly, with respect to *Mobile* usage, when gender inequalities are incorporated into the analysis, the positive effect on subjective well-being appears to be diminished. However, only in the case of secure internet servers, the moderation effect of gender inequality on the relation between ICT and well-being was not confirmed. We conducted robustness checks by replacing the dependent variable of well-being with prosperity as a measure of objective well-being. The same nonlinearities were observed in terms of the magnitude of the impact of ICTs on objective well-being, specifically for *Internet, Broadband, Tel* and *Servers*. However, for *Mobile*, the impact on objective well-being was not confirmed. The robustness checks also revealed a substitutability relationship between ICTs proxies (except for *Mobile*) and gender inequality: as gender inequality increases, the positive effect of ICTs on well-being (as proxied by prosperity) decreases.

The findings of this study have significant implications for policymakers. It confirms that the adoption of ICTs (Information and Communication Technologies) is positively associated with well-being. This implies that policymakers, particularly those from developing countries, should focus on creating policies that encourage the development of ICTs specific to their region, as these technologies significantly contribute to human well-being. Additionally, this study examines gender inequality as a moderating factor on the relationship between ICTs and well-being. Our empirical evidence shows that gender equality plays a crucial role in maintaining the positive effects of ICTs on well-being, which can be measured from both *subjective* and *objective* perspectives. Policymakers must prioritize initiatives aimed at eliminating gender disparities to achieve optimal results.

Although our study has some limitations, they could be seen as opportunities for future research. Specifically, our study focused on a large sample of 185 countries worldwide, and due to the complexity of the analysis, we did not conduct sub-sampling based on different criteria such as income classifications or geographical areas. Therefore, we suggest that future studies could be performed on sub-samples of countries classified according to various criteria such as stage of economic development, income classification or geographical area. Time dummies could also be included. This is especially important as gender inequality may be more prominent in certain geographical areas or income groups of countries (Dogan, 2016), which may also be influenced by other factors such as religion or cultural specificities. Therefore, we recommend that future studies consider these limitations and opportunities for research, which would contribute to advancing knowledge in this field.

Availability of data and materials

All the data provided from public database.

CRediT authorship contribution statement

Cristina Boța-Avram: Writing – review & editing, Writing – original

draft, Project administration, Data curation, Conceptualization. **Viorela Ligia Văidean:** Writing – review & editing, Writing – original draft, Validation, Formal analysis, Data curation. **Monica Violeta Achim:** Writing – review & editing, Writing – original draft, Supervision, Resources, Conceptualization. **Nawazish Mirza:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Resources.

Declaration of competing interest

The authors declare that they don't have any conflict of interest

Appendix 1

First, to demonstrate the association between ICT and life satisfaction, we plot them against each other for the whole sample (Fig. 1). Fig. 1 suggests a positive correlation with internet penetration rates among populations *(Internet)* and life satisfaction (*Happy*). The same positive correlation is depicted for the other ICT proxies on the one hand (*Mobile, Servers, Broadband, Tel*) and life satisfaction (*Happy*) on the other hand. It may be observed that higher levels of ICT penetration rates correlate with higher levels of life satisfaction, with the highest slope of the linear fit obtained for the direct impact of Mobile upon Happy.

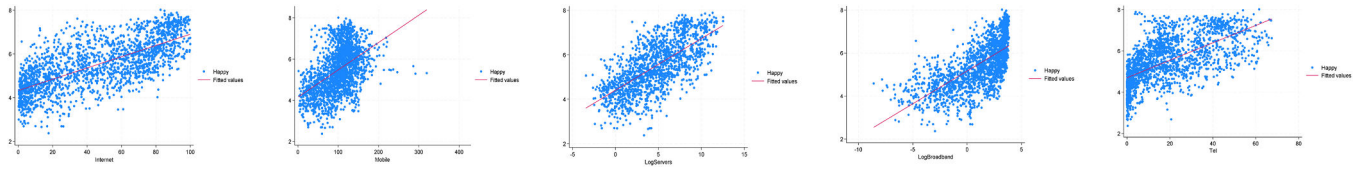


Fig. 1. Plot of ICT proxies against Happy.

Second, to demonstrate the association between gender inequality and life satisfaction, we plot them against each other for the whole sample (Fig. 2). Fig. 2 suggests a negative correlation between the Gender Inequality Index (*GenIneqI*) and life satisfaction *(Happy)*. It may be observed that higher levels of GenIneqI, that indicate poor performances, correlate with lower levels of life satisfaction, on average.

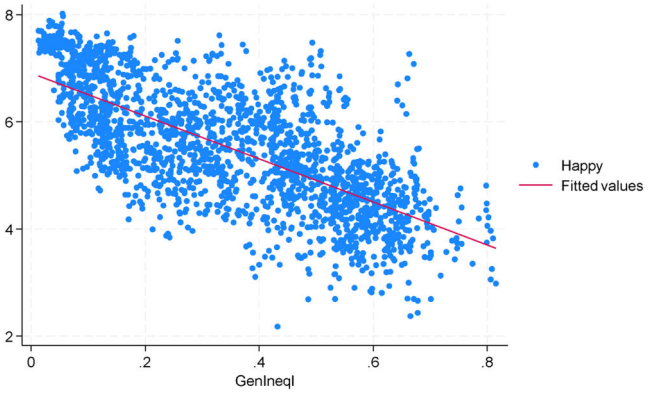


Fig. 2. Plot of GenIneqI against Happy.

The visual correlations are supported by the Pearson correlations (see Table 3 in the main body of this manuscript) showing the pairwise Pearson correlations between these variables.

The complete list of the countries included in this research work is the following: Afghanistan, Albania, Algeria, Angola, Argentina, Armenia, Australia, Austria, Azerbaijan, Bahamas, Bahrain, Bangladesh, Barbados, Belarus, Belgium, Belize, Benin, Bhutan, Bolivia, Bosnia and Herzegovina, Botswana, Brazil, Brunei Darussalam, Bulgaria, Burkina Faso, Burundi, Cambodia, Cameroon, Canada, Cape Verde, Central African Republic, Chad, Chile, China, Colombia, Comoros, Congo Democratic Republic, Congo Republic, Costa Rica, Côte dIvoire, Croatia, Cuba, Cyprus, Czech Republic, Denmark, Djibouti, Dominica, Dominican Republic, Ecuador, Egypt, El Salvador, Equatorial Guinea, Eritrea, Estonia, Ethiopia, Finland, France, Gabon, Gambia, Georgia, Germany, Ghana, Greece, Grenada, Guatemala, Guinea, Guinea-Bissau, Guyana, Haiti, Honduras, Hong Kong, Hungary, Iceland, India, Indonesia, Iran, Iraq, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kazakhstan, Kenya, Kiribati, Korea (North), Kosovo, Kuwait, Kyrgyzstan, Laos, Latvia, Lebanon, Lesotho, Liberia, Libya, Lithuania, Luxembourg, Macao, Macedonia, Madagascar, Malawi, Malaysia, Maldives, Mali, Malta, Mauritania, Mauritius, Mexico, Moldova, Mongolia, Montenegro, Morocco, Mozambique, Myanmar, Namibia, Nepal, Netherlands, New Zealand, Nicaragua, Niger, Nigeria, Norway, Oman, Pakistan, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Poland, Portugal, Puerto Rico, Qatar, Romania, Russia, Rwanda, Saint Lucia, Saint Vincent and the Grenadines, Samoa, Sao Tome and Principe, Saudi Arabia, Senegal, Serbia, Seychelles, Sierra Leone, Singapore, Slovakia, Slovenia, Somalia, South Africa, South Korea, South Sudan, Spain, Sri Lanka, Sudan, Suriname, Swaziland, Sweden, Switzerland, Syria, Taiwan, Tajikistan, Tanzania, Thailand, Timor-Leste, Togo, Tonga, Trinidad and Tobago, Tunisia, Turkey, Turkmenistan, Uganda, Ukraine, United Arab Emirates, United Kingdom, United States of America, Uruguay, Uzbekistan, Vanuatu, Venezuela, Vietnam, Yemen, Zambia and Zimbabwe.

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