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Female Human Capital and Economic Growth in Sudan: Empirical Evidence for Women's Empowerment

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Abstract: Human capital in general spurs economic growth. Female human capital in terms of education and health in particular is important for economic growth in countries where poverty and gender inequalities are pervasive, such as Sudan. This study aimed to investigate the role of female human capital in economic growth in Sudan, together with female labor force participation and women's participation in the national parliament. The study applied a basic autoregressive distributed lag model ARDL and a nonlinear (NARDL) accounting for structural breaks to time-series data over the period 1975–2021. The bounds tests revealed that female human capital variables and economic growth have a long-run equilibrium relationship. The empirical results revealed that female human capital has a negative effect on gross national income per capita (GNIP). However, female labor participation was found to have a significant positive effect on economic growth in both models. Prevalence of HIV/AIDS among women of age 14-25 has a significant negative effect on economic growth, which is likely also reflecting the negative effect of female human capital. Results also showed that women's participation in the parliament has positive and significant effect on economic growth in the short run only. The study argues for enhancing female human capital via female enrollment in education and through the promotion of women's health, including combatting HIV/AIDS. Effective female labor participation can be enhanced through reductions in women's vulnerability in employment and increasing their work in waged formal sectors. Women's political empowerment could foster long-term growth, but its quality aspects must be ascertained.

Keywords: female; education; health; labor force; women empowerment; NARDL; Sudan

1. Introduction

In economic growth theories, human capital enhances economic growth and development. Early contributions that brought human educational capital in theories and empirical verifications to the top of the research agenda were discussed in [1,2]. Since then, contributions from [3–6] have intensified the debate on the role of human capital, not only in education but also from health to economic growth. However, empirical studies have arrived at diverse results at the microeconomic and macroeconomic levels. At the microeconomic level, studies show that the returns on education are high, especially in developing countries [7–9]. At the macroeconomic level, some empirical studies find a weak relationship between economic growth and human capital, and some even show negative effects of human capital. For example, cross-section studies show a negative or at least insignificant relationship between human capital and economic growth [10-12]. Furthermore, panel data modelling such as in [13,14] also showed a negative or insignificant effect of human capital on economic growth. After discussing different problems associated with the methods and models used in the empirics of growth literature, and upon developing a generalized method of moments (GMM), Bond et al. [15] also showed an insignificant or negative relationship between human capital and economic growth.

Using different econometric methodologies, Ref. [15] argued that the nonexistence of a significant positive effect of human capital on economic growth could be due to misspecifications of the human capital model, inappropriate estimation methodologies, or an absence

of controls for governance and institutional variables. However, within the growth accounting framework, Young [16] argued that the higher growth in newly industrializing countries of East Asia was almost entirely due to increasing investment, increasing labor force participation, and education and was not because of rapid technological progress as concluded by empirical testing of the Solow growth model.

Yet until recently, and in terms of model specification, Baily et al. [17] argued that improvements in human capital have larger impacts on economic growth than implied by the neoclassical growth accounting modelling. The weak empirical relationship between human capital and growth according to [18] comes with diverting human capital from production to tax collection and public education, and the differences in institutional quality may involve a misleading negative correlation between gross domestic product and human capital.

However, recalling the early endogenous growth theory formulation and testing, it was argued that including human capital in the production process increases the share of capital, slows diminishing returns to capital, and makes the convergence rate low [5]. Regarding one aspect of human capital, education at all levels empirically proved to enhance economic growth [5,19]. It has been established as a fact that the higher the per capita income, the more years of schooling, and the better the health, the higher the human capital index (HCI) [20], not only aggregate human capital but capital related to gender equality, which spurs economic development, which intern fosters gender equality [21]. The channels of the positive effects of education capital involve a positive effect of human capital on physical investment, a negative effect on fertility, and a particularly positive effect on growth for given values of investment and fertility, in addition to its positive spill overs [4]. Furthermore, life expectancy as a measure of health status also provides a considerable portion of the explanation for economic growth and fertility [6].

The investigation of the role of women in development (WID) began in the mid-1970s, aimed at involving and integrating women in the development. However, WID has not brought significant results, particularly in the context of foreign aid for women's empowerment programmes [22]. One factor that limited the success of WID was that the approach was based on a preconception of male bias in foreign aid, foreigners' domination of the operation of funded projects [22], and perhaps competing paradigms such as between gender and development or women and environment. However, across countries and at the country level, the education levels of women and their spouses proved to be important determinants of women's labour force participation, which was also found to follow a U-shaped relationship with the level of development [23]. In particular, married women's income is related to the husbands' earnings as they are likely make labour supply decisions jointly, which makes women's income endogenous, in turn exerting income effects on women's labour supply that lead to limited work hours and withdrawal from the labour force [24].

The effects of husband's employment and income on wife's career and income were empirically verified for cases of dual-career couples in the Gulf Cooperation Council countries, particularly where sociocultural settings of the hosting country limit expatriate women's careers, negatively impacting their career capital [25]. This finding is of high relevance to the case of Sudan: More than 2 million Sudanese families live abroad, and while husbands work in formal jobs, their wives stay at home taking care of children and overall domestic family issues. During the two civil wars (1956 to 1972) and (1983 to 2004) and then since 1990 due to political instability, masses of Sudanese migrated to neighbouring countries, namely Egypt, Libya, Saudi Arabia, and the Gulf countries, as well as to the Netherlands, Germany, the United Kingdom, the United States, Canada, and Australia. Another problem related to health facing Sudanese women living abroad is a higher prevalence of HIV/AIDS compared with domestic women. One example study by Jeffery et al. [26] documented that the incidence rates of HIV/AIDS were higher than the national average among a sample of Sudanese immigrant women in Denmark, who had little knowledge about HIV/AIDS, its prevention methods or knowledge of condom and use, particularly women with low education levels.

2. Women Health, Political and Economic Position in Sudan

2.1. Women's Political Participation in Sudan

Since ancient times, women in Sudan have maintained a strong political leadership, ruling as queens known as Kandakas in the Kush kingdom. Recently, young girls led the demonstrations in the 19 September 2018 Revolution that overthrew President Omer Albashir have been described as Kandakas. However, the women rights and feminism movement that began to form since the early years of the 20th century have been due to progress in girls' education. The first formal school to teach girls in Sudan was established in 1907 by Babiker Badri [27]. Later, the British established girls' schools during their rule of the country, mainly focusing on preparing girls to become teachers, midwives, and nurses [27]. At that time, educated girls were considered better for marriage than non-educated ones [27]. Female graduates later led the formation of several women's unions that were concerned with enhancing women's education and working conditions. The first women's association emerged during the 1940s under the Sudan People's Liberation Movement [28]. Women's participation in political activities in modern Sudan started with the establishment of the Sudan Women's Union (SWU) in 1952, three years before Sudan's independence. The SWU was chaired by the first Sudanese physician and women's rights activist Khaldah Zahir. This union demanded equal wages, maternity leave, pensions, and the promotion of gender equality [29]. In 1955, the SWU established a magazine called the Voice of Women. However, the military government led by General Ibrahim Aboud, upon a military coup in August 1958, dissolved all civil society organisations (CSOs), in November 1958, including the SWU; however, Voice of Women magazine continued publishing owning to its private ownership [28].

In the 1958 elections, only graduate women from universities and high schools were allowed to vote, but they could not be candidates for political positions [30,31]. However, following the October 1964 revolution which overthrew Aboud, all Sudanese women were allowed to vote and to be elected to the national parliament [27,31]. Of two women who ran for election, Fatima Ahmed Ibrahim from the Sudanese Communist Party was the first women to be elected to the national parliament in 1965 [30]. Meanwhile, some women leaders deseeded from the SWU, believed to be from the Muslim Brotherhood front, and established the Women Front after the 1964 revolution [28]. In 1968, a Committee for the Defense of Working Women's Rights was formed from the SWU, the Workers' Chamber—which includes the trade union, the teachers union, the employees union, and the students' union. This women's movement managed to include working women in the civil services pension system and amended the work law to grant working women fully paid maternity leave for two months before and after giving birth provided that they had completed one year of work. At that time, those achievements were milestones in women's political and economic empowerment.

Upon the military takeover by Gaafar El-Nimiry in May 1969, the SWU was dissolved in 1971. The El-Nimiry regime re-established the Sudanese Women Union with new female leadership. However, under the same military regime, in 1973, a quota system for women's participation in the parliament was adopted under the so-called the Socialist Union, the only politically active party at time. In 1985, after a social uprising which threw out El-Nimiry, the SWU came back to work openly, and the Democratic Women's Union (DWU) was established by some political parties and some politically independent women [32].

In June 1989, another military coup led by Omer Albashir took control of the country, but in the same year the so-called National Salvation Government reserved 10% seats for women in the parliament, renamed the National Assembly. However, the government nominated a number of women leaders in the executive body while many previously working women were fired under the so-called 'public interest' [31]. The government adopted a system of training for women within the newly created paramilitary force—the

Popular Defence—and made it a condition for women's training and promotion. In 1990, the Sudanese Women General Union (SWGU) was formed and controlled by the ruling National Congress Party. The old pioneers of the SWU leadership were almost neutralized, and their activities were hindered, mainly due to differing ideologies of the ruling Islamism and the opposing communists. However, the SWU strived and widely believed that it contributed to the feminist movement and the liberation of women in Sudan [33]. As a result, it stands as the only women's union in the world to receive the United Nations Prize in the Field of Human Rights in 1993 [34].

In 1995, a third constitutional decree was issued that reserved 8% of seats for women, resulting in 21 women's seats in the parliament [31]. Furthermore, the Comprehensive Peace Agreement (CPA) signed in January 2005 between the government of Sudan and the Sudan People Liberation Army/Movement (SPLA/M), which ended the war in South Sudan, represented a turning point in the history of the country. In 2007, the Sudanese Women Parliamentarian Association was established to enforce the participation of women in the federal and state parliaments, which gave the women the right to handle political issues, review budgets and other parliamentarian work [31]. Accordingly, the Sudanese Electoral Laws of 2008 were to usher in a democratic transformation toward the presidential election in 2010 and the enactment of a new interim constitution which generalized a female representation ratio of 25% percent in the legislative bodies throughout the country [31]. However, the 25% quota system has largely been along political affiliation lines, with women representatives following the party agenda, and it has had little success in promoting women's gender equality and democratic rights [30,31,35].

Table 1 presents the most important women's CSOs, non-governmental organisations (NGOs) that have been striving to improve women's economic and political empowerment in Sudan.

Notwithstanding that, after the 1989 coup, all NGOs were dissolved and had to register again in 1990. A major problem besetting effective efforts at achieving women's economic and political empowerment, which has been evolving for decades, is the divide between the traditional Sudanese women's movements (Marxist or Islamist) and the Sudanese feminism movements. For more elaboration on these contested women issues in Sudan, the reader is directed to [28,33].

Organisation	Establishment and Remarks
Sudanese Women Union (SWU)	Established in 1952. The main and pioneer women's civil society NGO. Renamed many times according to government interventions and orientations; the longest was the SWGU, since 1990.
Babiker Badri Scientific Association for Women's Studies (BBSAWS)	Established in 1975 as the first scientific association concerned with women's studies. In 1985, the BBSAWS's Committee on the Eradication Female Circumcision organized an international conference on female genital mutilation FGM [36]. Yusuf Badri, son of Babiker, was the founder of the Ahfad University for Women (AUW), a Sudanese university solely for women, in 1966 as a non-governmental and non-profit university in Sudan. As of 2020, the university had graduated near 20,000 women and had more than 1000 female post-graduates. It currently has over 7300 students from 26 countries.
Sudanese Women Empowerment for Peace (SuWEP)	Established in 1994 by women from both South and North Sudan. The number of women who are directly involved and active within SuWEP exceeds 1000, excluding beneficiaries [37].
CAFA Association	Established in 1996 at the AUW. The university has a Regional Institute of Gender, Diversity, Peace and Rights that undertook a project titled The Introduction of the Quota System in Sudan and its Impact in Enhancing Women's Political Engagement. CAFA also works in fighting harmful traditional practices against women such as FGM, widely practiced in Sudan based on beliefs in girls' 'purification' [34].

Table 1. Women's Civil Society NGOs in Sudan.

Table 1. Cont.

Organisation	Establishment and Remarks
Al Gassim for Humanitarian Aid and Development (AGHAD)	Established in 2010. The secretary general of AGHAD was quoted as saying 'women's empowerment starts at the grass-roots level and, from here, we can help not only women in Sudan but women all over the world', [38]. AGHAD works to mobilize assistance to provide food to the vulnerable, support orphans in the poor neighbourhoods of Khartoum, help internally displaced people (IDPs) across the country and empower women to protect them against gender-based violence. According to [38], the organisation managed to provide daily meals to more than 18,000 people living in poor neighbourhoods in Khartoum. AGHAD has been working to mitigate some of the impacts of COVID-19 in terms of increasing prices, job losses and increasing poverty and hunger across the country by providing daily necessities for needy people. A women's empowerment programme at AHGAD was able to educate over 3000 women to have skills for income-generating activities and be able support their children and families [38].
Sudanese Women Parliamentarian Association (SWPA)	Established in 2007 by women in the national parliament. Has two regional subsidiaries, the Women Parliament in Gezira State and the Women Forum in the White Nile State.
Sudanese Women in Science Organization (SWSO)	Established in 2013. SWSO works under the umbrella of the Organization for Women in Science for the Developing World (OWSD) and the UNESCO. SWSO is committed to empowering Sudanese women and achieving gender equity through science and scientific research. It works to boost the effectiveness and participation of all Sudanese women by raising public awareness about women rights, building women's leadership capacity and strengthening women's economic development. Its priorities are to enforce equity in education, scientific research, job opportunities and leadership and political participation [39].
The Sudanese Organisation for Research and Development (SORD)	Established in 2007. SORD implemented many projects and programmes in three interrelated themes of gender justice and women rights, sustaining livelihoods for women and men and enhancing the capacities of CSOs. Some projects have been solely devoted to dealing with school dropouts, supporting IDPs in camps, women's empowerment and access to legal and economic services, combating HIV/AIDS and child and forced (girl) marriage (estimated at 32 to 49% in Eastern Sudan [40]. SORD has been financially supported by many donors including the EU, Goal Ireland, Manitese, ICCO, Inter Pares and NOVIB [40]. In May 2004, the founder of SORD co-founded the Gender Center for Research and Training (GCRT) in Sudan and was presented with the 2004 Betty Plewes Fund Award, receiving a grant of \$15,000 from the Canadian Council for International Cooperation for research and policy development on issues of priority to women [41].
Sudanese Women Economists Association (SWEA) established in June 2020	Established in 2020 by young women recently graduated in economics, mainly from the University of Khartoum. They engaged in many activities for economic empowerment of women based on economic and political studies conducted by women scholars. They also produce a podcast called Hiwarat "Debates".

Source: Authors compilation.

Women's health can generally be indicated by life expectancy at birth, which is also an indicator of overall health status in a country. Female life expectancy (LEF) in Sudan is greater than that for men (LEM), particularly over the working age of 14 to 64 years. In 1990, LEF averaged 57 years, while LEM averaged 54 years; these increased to 64.5 years for women and 56.6 years for men in 2010, and in 2020, they reached 67 years and 63 years for women and men, respectively. Another major indictor of female health is the maternal mortality ration (MMR). MMR in Sudan was 667 per 100,000 livebirths in 2000, declined to 408 in 2010 and standing at 253 in 2020 [42]. LEF and MMR are related to internal displacement, nutrition and infectious diseases including HIV/AIDS as well as the historical lack of maternal care services, and where the prevalence of HIV/AIDS among women is higher than among men [43].

As for combating HIV/AIDS, the United States Foreign Aid (USAID) noted remarkable improvements during 2015–2020 with regard to increasing coverage with HIV prevention services. However, HIV service coverage declined in 2019 due mainly to the political instability and reduction in funds [44]. Furthermore, since the outbreak of COVID-19, coupled with increasing political instability, economic downturn in Sudan and reduced international assistance, the HIV/AIDs situation in Sudan is only expected to worsen,

particularly among vulnerable poor people and women. However as noted in various reports, women and girls in Sudan face strong social pressures and barriers which restrict their access to information about sexual and reproductive health, thus rendering them more vulnerable to HIV. It has been documented that the prevalence of HIV in Sudan is related to sexually risky behaviours and very low use of condoms, 1.8% in a sample of 870 participants in a study on HIV knowledge assessment in Sudan [45]. This remained unchanged recently: the majority of HIV infections in Sudan are found to be sexually transmitted or associated with pregnancy and childbirth. While 77% of women were found to be aware of HIV/AIDS, only 33% of women knew about the means of mother-to-child transmission [45]. The HIV rate among young population aged 15–24 years was found to be higher for women than for men [46]. Although SNAP was launched in 1987, until 1998, the Sudanese government denied that HIV/AIDS posed any significant health threat to Sudanese people, and only in 2004 did the government formally begin planning to address HIV/AIDS, Bechtold [47]. All in all, the use of condoms to combat HIV/AIDS is a very contested issue between feminism, Islamism, Marxist and liberal women movements [28,47].

2.2. Women Economic Participation in Sudan

The populations of women of all ages have almost always exceeded those of men in Sudan, particularly among the working-age population. For example, in 2003, there were 10,588,634 women and 10,571,199 men ages 15 and 64 years, representing 54% of total population [48]. There were 5,199,511 women and 5,188,637 men, 9,380,466 women and 9,183,701 men and 12,474,073 women and 12,312,389 men in 1990, 2010 and 2020 respectively in the age range of 15 to 64 years [42]. However, women's participation in the labour force (LFF) and organized, paid economic activities has always been far lower than that of men in Sudan's course of economic and social development. LFF rate of total female population ages 15 to 64 years was estimated at 24%, 29%, 29% and 31% in 1990, 2000, 2010, and 2020 respectively, while the corresponding figures for men were 77%, 74%, 71% and 69%, respectively [42]. This widening employment gap only means a widening earnings gap between women and men. Given that there have always been more women ages 15 to 64 years than men, it cannot be imagined that poverty can be reduced by focusing only on increasing total employment in the country.

LFF increases or decreases with economic growth given other influencing factors such as fertility, the willingness to have more children and the incomes for employed married women. In fact, as wage work increases, fertility tends to decline and vice versa, Goldin [23]. Civil laws and society traditions and customs also restrict rights to income-generating opportunities for women in low-income countries where husbands can restrict a wife's employment outside the home, such as in Bolivia, Guatemala and Syria, Dollar and Gatti [49]. In Sudan, although restrictive laws do not exist, beliefs, habits, and social customs limit the chances of a woman's being employed in the formal paid sector, particularly in rural areas. In addition, existing strong social stigmas also reduce married women's work outside the home, as Goldin [23] observed.

Some studies document that the labour force participation rate for married women first declines and then rises with economic development, following a U shape both across the process of economic development and over time [23]. The initial decline in the participation rate is believed to be due to a shift in production from the household, family farm or and small business to the wider market, with strong income effects. When women are poorly educated, their only wage labour outside homes and family farms is in manual work, against which a strong social stigma exists, but when women are educated, they enter white collar work, against which no social stigma exists [24].

It is observable that women in rural areas throughout Sudan engage in many economic activities. Women of different ages, perhaps from age seven to age seventy, work mainly in agriculture and family farms. Their main activities include the manual planting of seeds, mostly practiced by young girls from age 10 to age 25 years; harvesting sorghum, millet and ground nut, paid hourly cash or in kind payments; cotton harvesting with cash earnings based on the quantity of cotton picked; fetching water from wells and centralized tap water carrying it on their heads or on donkeys—unpaid work; fetching biomass remains and residues from woods, bushes and animal dungs for cooking and heating purposes, which is the overwhelming energy source use in rural areas where modern energy sources such electricity or diesel-powered generators are very limited or non-existent. In fact, biomass energy sources are collected by rural women from age 10 to almost 70. Married women also 100% of the housework such as cooking and child care, including preparing children for school, caring for husbands, and caring for parents if they are alive and have no one to take care of them. Such activities and time allocation likely increases overall poverty prevalence in the country.

In sum, women in rural areas participate widely in many economic activities, but all are informal jobs and overwhelmingly unpaid work or at best with limited wage incomes, akin to what [22,24] observed. Such work structures and patterns for women greatly restrict their economic independence and make them vulnerable to men's abuse. In fact, the current situation of women's health and economic participation in Sudan is largely similar to what was described by [22], in quoting different views of foreign aid organisations.

Women in Sudan suffer from the consequences of increasing divorce rates due to deteriorating economic conditions, the migration of men outside of Sudan and secret and informal marriages [50]. Alzain [50] and Alamin [51] put the blame on Sudan's Personal Status Law of 1991, which needs to be replaced with a family law that gives full consideration to women's rights in marriage, divorce, protection against violence and custody matters. The 1991 law was amended in 2020 to allow women to travel abroad without their father's permission and criminalized the GFM [52]. However, practices and divorce rates leave women in Sudan more vulnerable as heads of households who must take care of their children under dire financial constraints and few opportunities for income-generating activities in either the formal or informal sectors, especially in urban and semi-urban settings. Such situations are also aggravated by the internal displacement of both men and women, which is a protracted phenomenon in Sudan due to prolonged armed conflicts and natural disasters [53].

The increasing numbers of households headed by women in Sudan and in developing countries in general face mounting risks and challenges in maintaining the family's basic needs including food, water, education, health care and energy, mostly because they lack income-generating opportunities. To mitigate the impacts of the burden of poverty on women, as an example, a non-profit charity organisation called Bangladesh American Society of Muslim Aid for Humanity Inc. (BASMAH, Boca Raton, FL, USA) implemented a programme of distributing free sewing machines with training centres across Bangladesh. The programme aimed to improve the skills of poor women to enable them to open small businesses in their households. The programme calculated the cost of a sewing machine at \$125 and training costs at \$50 and managed to train over 155 poor women [54]. The organisation also provides assistance to students, orphans and refugees from Myanmar, among whom are girls and women. Such programmes are highly needed in Sudan, and CSOs, NGOs and international concerned organisations as well as government agencies need to cooperate in providing funds for women income-generating activities in the country, especially in the conflicts affected areas.

The objective of this study is to investigate the effects of female human capital and women's economic and political empowerment on economic growth in Sudan. This study is the first of its kind that explores these interlinkages so that reasonable findings can be generated for bettering women's economic and political empowerment in Sudan.

3. Literature Review

The links of human capital and economic development have been well documented in the Human Development Index (HDI) of the World Bank since the early 1990s and in the recently developed HCI [55,56]. However, both the HDI and HCI mask the role of gender differences and gender inequalities in economic development. Gender equality and overall economic development are intrinsically linked and mutually reinforcing [21,49]. Elevating the relative status of women, for example by allowing them equal access to education and employment, contributes to expanding the economy at national levels, Klasen [57,58]. On the other hand, limiting the capacity of women to contribute productively hampers a country's ability to advance the living standards of its citizens [21,58].

According to [49], increases in per capita income lead to improvements in gender equality in education and health, and investments in girls promote economic growth. Using cross-country and panel regressions, Ref. [57] showed that gender inequality in education has a direct impact on economic growth through lowering the average quality of human capital. The author found that gender inequality affects economic growth indirectly through its impact on investment and population growth and that gender inequality in education prevents progress in reducing fertility, thus hindering well-being improvement in developing countries. Higher gender inequality appears to increase poverty as women allocate more resources to food, health care and the education of their children than men do; meanwhile, female education has been found to be one of the most important determinants of the effects of strengthened growth on poverty [58].

It has long been argued that women are good for economic growth and economic growth is good for women [21]. This dynamic process can be enhanced by initiating and promoting women's projects and small businesses. This argument was verified with examples of projects for women's economic empowerment in Pakistan and elsewhere [59–61], in Bolivia, Mozambique, North West China, Tanzania, Uganda and the USA [62]. Such projects also benefit the wider society, as they increase the financing of family businesses, children's education and improving household nutrition. Such indirect benefits serve countries committed to the growth of trade and commerce, and they are necessary conditions for sustainable development [62].

Women's health and education capital interacts with fertility and economic growth. In Barro–Becker type modelling, Ref. [63] found that total fertility rate falls when child mortality declines and economic growth improves. However, it has been found that factors other than declining child mortality are responsible for the large decline in net fertility rates in developed countries. In the case of Sudan, [64,65] found that reduced maternal mortality, child mortality and fertility were all strongly associated with increasing income.

Hosoya [66], using a panel data set from 1960 to 2000 for 24 members of the OECD, estimated OLS and instrumental variables and found that both health and education capital positively and similarly affect growth. Health expenditure was also showed to impact growth positively. Furthermore, Ref. [67], in a sample of developed and developing countries, used dynamic panel data and the GMM, found that human capital has positive effects on economic growth, with mixed effects of corruption on economic growth, and that democracy has a positive effect on economic growth in developed countries, while it has a negative effect on growth in West and South Asia countries.

In the case of Egypt, Hefnawi Ref. [9] found a direct relationship between stock of physical capital and investment in health and economic growth. They found a negative effect of investment in education capital on economic growth, explained by low-quality public education as well as a negative effect of labour force on economic growth. However, at a microeconomic level, they found that households' education and health status have positive effects on wage growth. Yet for the same country, Ghalwash [68] found that corruption leads to inefficiencies of government expenditure, thus reducing human and physical capital accumulations and accordingly hampering economic growth.

Using a survey data from Congo, Ref. [69] found that increases in household wealth significantly improves girls' nutrition, but they found a negative relationship between a mother's health index and the child's growth, with high and closely spaced births weakening the mother's and child's health; mother's education and knowledge about nutrition was found to improve children's health.

In a comparative study, Ref. [17] investigated the differences in roles of human capital in the United States, Germany and Japan. They found that growth has been slow in the three economies, but with notable larger effects of education quality, workers' skills, innovation and the role of women in the USA and Germany than in Japan. In a sample of a panel of 180 developed and developing countries from 1981 to 2012, [70] found that increases in expenditures on public and private education enhance education quality, which increases the number of skilled labourers and productivity, with physical capital and trade openness enhancing economic growth.

4. Statistical and Econometric Modelling

4.1. Selection and Definition of Variables and Data

This study adopts time-series statistics and econometric methods. The methods include descriptive statistics, unit root tests, vector autoregressive (VAR) modelling and bounds test cointegration methods, with error correction modelling. The study uses time-series data over the period 1975 to 2021 for Sudan. An analytical framework linking the components of female human capital, economic and political participation, physical capital and HIV/AIDS with economic growth is depicted in Figure 1.



Figure 1. The analytical framework. The solid lines show the direction of expected relationship between FHC and economic growth (GNIP). The circle contains female health (LEF) and education (SEF), women nutrition (PAW), fertility (FER), and prevalence of HIV among women to female labour force participation (LFF). These variables jointly determine female human capital (FHC). The variables AWR, WPP and FCF are expected to weakly affect the factors affecting LFF and showed by the dashed lines, meanwhile the same variables are expected to affect economic growth more directly as shown by the solid lines flowing to GNIP.

This study follows [49,57,58] in selecting the most relevant variables of female human capital and women's empowerment in their relationships to economic growth and development. The variables selected pertain to girls' and women's health and education in relation to economic growth, nutrition, physical capital and savings as well as women's political empowerment. They include women' access to education measured by enrolment in primary school; improvement in health (measured by women's life expectancy at birth and at ages 15 to 64); and women's empowerment (measured as the percentage of women in the national parliament). According to [49], these different measures are likely highly positively correlated. More importantly, these measures of women's human capital and empowerment are expected to be strongly positively correlated with per capita income. The selected variables are defined in Table 2, and an analytical framework is depicted in Figure 1. Variable Definition **Data Source** GNIP Real gross national income per capita at 2015 prices WDI Female human capital, average women's life expectancy at birth (LEF-female health capital) and female enrollment in primary school (SEF—female education capital); these FHC WDI are both flow variables and directly observable measures of human capital; they also reflect the quality of public institutions. PAW Prevalence of anemia among women of age 14–64 (nutrition) WDI FER WDI Fertility rate of women during their reproductive life Prevalence of HIV among women ages 14-64; a dummy variable is used for HIV HIV WDI prevalence, with zero from 1975 to 1989 or 1 from 1990 to 2020 LFF Women's labour participation rate (as % of total labour force) WDI AWR Access to water in rural areas (as % of rural population) WDI WPP Women's political participation (percentage of women in the national parliament) WDI, [30] FCF WDI Gross fixed capital formation (as % of GDP), a measure of physical capital

Table 2. Variables and Measurements.

The analytical framework by no means assumes a linear relationship between the specified variables and economic growth. The transmission could be direct or indirect and symmetric or asymmetric, mediated through the effects of factors such as nutrition (PAW), fertility [23,24] and prevalence of HIV on women's' human capital, to economic growth in a dynamic process. It was also noted that girls' return to schooling could take many years to materialise [71]. These factors also affect female labour participation (LFF), which contributes directly to the determination of economic growth. Meanwhile, factors affecting FHC are also affected by other factors such as access to water (AWR), women's political participation (WPP) and savings and investment (FCF). Domestic saving is important in financing the accumulation of human capital, since this type of capital cannot be financed by foreign borrowing [5]; more important is that the share of physical capital and the share of human capital tend to enhance each other and lead to higher growth [72]. In models of human capital and economic growth, savings and investment—both as percentage of total output were widely used—as they affect and affected by education and health human capitals [6,72,73]. LEF is a broad indicator of the health of the population that has been shown to be a significant predictor of future economic growth. High LEF reflects the economic benefits of low infant mortality, low morbidity in the population and a longer time horizon for the accumulation of human capital [6]. In explaining growth in Africa, [74] found that life expectancy at birth contributes positively to economic growth but at a decreasing rate.

4.2. Statistical Analysis

The study follows descriptive statistical analysis and econometric time-series methods. The statistical analysis starts with major indicators for women's economic empowerment in Sudan. Figure 1 shows the most important and relevant gender gaps for women's employment, namely, employment vulnerability for women (WEV) and for men (MEV) and waged and salaried women (WSW) and men (WSM). Over the period 1990 to 2021, WEV averaged 67.77%, while MEV averaged 52.84, with a gender gap that averaged 14%. WSW averaged 31.15%, and WSM averaged 44.29%, [42] with a gender gap that averaged 13.14%. These gaps are shown in Figure 2. This indicates the much higher vulnerability of women compared with men and, correspondingly, women's fewer economic opportunities and lower empowerment compared with men. Such wide gaps translate into other vulnerabilities for women, particularly during times of poor health or economic and political instability crises, for instance the protracted history of civil and armed conflicts and mass displacement in Sudan.



Figure 2. Employment Gender Gaps. Note: Author's calculations based on Data Sourced from the World Bank, WDI, 2022 [42].

Figure 3 presents a graphical analysis of the study variables on their natural logarithm values (Log). Figure 3a–i show that increases in FHC, increases in LFF, increases in AWR and increases in WPP are associated with increases in GNIP. On the other hand, declining PAW and FER are likely strongly associated with increasing GNIP.



Figure 3. Cont.



Figure 3. Plots of the logs of the study variables. (a): Log(GNIP); (b): Log(FHC); (c): Log(LFF); (d): Log(FER); (e): Log(AWR); (f): Log(WPP); (g): Log(FCF); (h): Log(HIV); (i): Log(PAW).

Table 3 presents the basic descriptive statistics for and correlations of the study variables. All variables appear non-normally distributed except fertility rate according to Jarque–Bera statistics and the corresponding probability values.

Statistics	GNIP	FHC	LFF	PAW	AWR	FER	HIV	WPP	FCF
Mean	1238.519	59.49	26.15	42.03	38.78	5.60	0.16	13.19	17.21
Median	1044.025	56.48	27.74	44.23	35.25	5.58	0.20	7.72	15.94
Maximum	2218.416	73.31	31.26	46.27	53.50	6.94	0.30	40.52	29.32
Minimum	737.690	52.51	18.67	36.60	30.73	4.12	0.00	4.00	4.33
Std. Dev.	481.594	6.58	3.57	3.52	7.44	0.88	0.13	11.34	6.49
Skewness	0.950	0.77	-0.45	-0.50	1.04	0.01	-0.11	1.10	0.16
Kurtosis	2.434	2.16	1.90	1.56	2.53	1.73	1.34	2.96	2.31
Jarque-Bera	7.866	6.14	4.07	6.14	9.02	3.23	5.61	9.76	1.15
Probability	0.020	0.046	0.131	0.046	0.011	0.199	0.060	0.008	0.563
Observations	48	48	48	48	48	48	48	48	48
Correlations	GNIP	FHC	LFF	PAW	AWR	FER	HIV	WPP	FCF
RGNIP	1.00								
FHC	0.94	1.00							
LFF	0.72	0.85	1.00						
PAW	-0.94	-0.97	-0.83	1.00					
AWR	0.96	0.97	0.79	-0.93	1.00				
FER	-0.83	-0.94	-0.96	0.92	-0.88	1.00			
HIV	0.79	0.88	0.94	-0.89	0.79	-0.96	1.00		
WPP	0.94	0.98	0.79	-0.94	0.97	-0.89	0.82	1.00	
FCF	-0.05	0.03	0.21	-0.17	-0.16	-0.17	0.34	-0.06	1.00

Table 3. Descriptive statistics and correlations.

The highest correlation coefficients are found between real GNIP and access to water in rural areas, female human capital, women's political participation and physical capital formation, with positive signs as expected. Prevalence of anaemia among women and fertility are negatively and significantly correlated with real GNIP. Female human capital is highly positively correlated with women's political participation, access to water in rural areas, physical capital formation and female labour participation but negatively highly correlated with prevalence of anaemia among women and fertility rates, all as excepted. Women's political participation is found to be correlated with access to water in rural areas and physical capital formation. These correlations between the dependent variable (GNIP) and the independent variables as well as between the independent variables themselves indicate that female human capital and economic and political conditions reinforce each other and more importantly in the expected direction. They also suggest strong co-movement over time or cointegration in the language of econometrics, which is explored by the appropriate econometric methods.

4.3. Econometric Estimation Procedures Unit Root Tests

Before the estimation process, the properties of the time-series data are checked by applying the Phillips–Perron [75] and the Dickey–Fuller generalised least square (DF-GLS) de-trending test developed by [76], in order to investigate their stability in terms of stationarity over time. Unit root tests are implemented in the scenarios of constant (C) and constant and linear trend (C, T). Table 4 summarizes the unit root test results.

Table 4. Summary Results of Unit Root Tests.

Variable	PP. C		РР. С, Т		DF-GLS C		DF-GLS C, T		Order of
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	
L(GNIP)	0.354	-4.988 **	-2.245	-5.330 **	0.019	-4.978 **	-1.360	-5.487 **	I(1)
L(FHC)	1.821	-5.823 **	-1.239	-6.365 **	0.585	-3.201 **	-1.266	-6.299 **	I(1)
L(LFF)	-2.927 *	-9.750 **	-3.028	-13.924 **	0.104	-1.546	-1.589	-8.643 **	I(0); I(1)
L(FER)	3.994	-6.061 **	-3.264	-8.096 **	-1.202	0.443	-0.945	-2.724	I(1)
L(PAW)	-0.384	-4.220 **	-1.436	-4.164 **	-1.061	-1.310	-1.826	-1.801	I(1)
L(AWR)	0.575	-3.721 **	-1.151	-3.761 **	-0.598	-2.064 **	-2.554	-2.488	I(1)
L(WPP)	2.190	-6.895 **	-2.102	-12.160 **	1.455	-6.633 **	-1.678	-5.718 **	I(1)
L(FCF)	-2.935 *	-11.810 **	-2.780	-12.965 **	-2.762 **	-5.791 **	-2.762	-7.028 **	I(0); I(1)
HIV	-0.663	-7.208 **	-2.089	-7.191 **	0.019	-7.065 **	-2.010	-7.164 **	I(1)

**, * indicates significance at 1% and 5% level respectively.

The unit roots tests reveal that all the variables of concern follow an order integration at first difference I(1) except LFF and FCF, which are found to be stationary at both I(0) and I(1). Stationarity of variables is more prevalent in the case of C only, not in the case of (C, T), and this was consistent for both the PP and DF-GLS tests. This justifies the use of the autoregressive distributed lag (ARDL) bounds tests model of [77,78], tested in the case of restricted constant without trend. An ARDL with error correction term (ECM) is specified in Equation (1):

$$\begin{aligned} \Delta L(GNIP)_{t} &= \alpha + \sum_{i=1}^{q} \beta_{1i} \Delta L(GINP)_{t-1} + \sum_{i=0}^{q} \beta_{2i} \Delta L(FHC)_{t-1} \\ &+ \sum_{i=0}^{q} \beta_{3i} \Delta L(LFF)_{t-1} + \sum_{i=0}^{q} \beta_{4i} \Delta L(PAW)_{t-1} + \sum_{i=0}^{q} \beta_{5i} \Delta L(FER)_{t-1} \\ &+ \sum_{i=0}^{q} \beta_{6i} \Delta L(WPP)_{t-1} + \sum_{i=0}^{q} \beta_{7i} \Delta L(AWR)_{t-1} + \sum_{i=0}^{q} \beta_{8i} \Delta L(FCF)_{t-1} \\ &+ \sum_{i=0}^{q} \beta_{9} \Delta HIV_{t-1} + \beta_{10} L(GNIP)_{t-1} + \beta_{11} L(FHC)_{t-1} + \beta_{12} L(LFF)_{t-1} \\ &+ \beta_{13} L(PAW)_{t-1} + \beta_{14} L(FER)_{t-1} + \beta_{15} L(WPP)_{t-1} + \beta_{16} L(AWR)_{t-1} \\ &+ \beta_{17} L(FCF)_{t-1} + \beta_{18} HIV + \eta ECT_{t-1} + \mu_{t} \end{aligned}$$

$$(1)$$

A nonlinear (NARDL) that takes into account the possible structural shifts associated with prevalence of HIV/AIDS among women from the year 1990 as the first year in which HIV/AIDS was documented is specified in Equation (2):

$$\Delta L(GNIP)_{t} = \alpha + \sum_{i=1}^{q} \beta_{1i} \Delta L(GINP)_{t-1} + \sum_{i=0}^{q} \beta_{2i} \Delta L(FHC)_{t-1} + \sum_{i=0}^{q} \beta_{3i} \Delta L(LFF)_{t-1} + \sum_{i=0}^{q} \beta_{4i} \Delta L(PAW)_{t-1} + \sum_{i=0}^{q} \beta_{5i} \Delta L(FER)_{t-1} + \sum_{i=0}^{q} \beta_{6i} \Delta L(WPP)_{t-1} + \sum_{i=0}^{q} \beta_{7i} \Delta L(AWR)_{t-1} + \sum_{i=0}^{q} \beta_{8i} \Delta L(FCF)_{t-1} + \sum_{i=0}^{q} \beta_{9} \Delta HIV + \beta_{10} L(GNIP)_{t-1} + \beta_{11} L(FHC)_{t-1} + \beta_{12} L(LFF)_{t-1} + \beta_{13} L(PAW)_{t-1} + \beta_{14} L(FER)_{t-1} + \beta_{15} L(WPP)_{t-1} + \beta_{16} L(AWR)_{t-1} + \beta_{17} L(FCF)_{t-1} + \beta_{18} HIV + \eta ECT_{t-1} + \beta_{19} (dummy 1990) + \mu_{t}$$

$$(2)$$

where *q* is the lag length and Δ is the difference operator. Equations (1) and (2) are estimated with OLS to explore the long-term relationships among the variables via the joint significance of their lagged-level values. The null hypothesis of no cointegration for GNIP as the dependent variable is:

$$H_0: \ \beta_{10} = \beta_{11} = \beta_{12} = \beta_{13} = \beta_{14} = \beta_{15} = \beta_{16} = \beta_{17} = \beta_{18} = 0$$

against the alternative hypothesis of existence of cointegration as:

 $H_0: \ \beta_{10} \neq \beta_{11} \neq \beta_{12} \neq \beta_{13} \neq \beta_{14} \neq \beta_{15} \neq \beta_{16} \neq \beta_{17} \neq \beta_{18} \neq 0$

The test decision rule is that the bounds test's F-statistics must be greater than the upper bounds critical values for the conclusion of existence of a cointegrated relationship. For selecting the optimum lag order, a vector autoregressive (VAR) model is estimated. For estimations of the ARDL and the NARDL, an identical optimum lag order of 3 is selected according to the criteria presented in Table 5.

Table 5. Lag Order Selection Criteria.

Lag	LL	LR	EPE	AIC	SC	HQ
0	591.779	NA	4.56×10^{-23}	-25.9013	-25.540	-25.767
1	1050.409	713.425	$2.51 imes10^{-30}$	-42.685	-39.072 *	-41.338
2	1131.717	93.956	$3.84 imes10^{-30}$	-42.699	-35.833	-40.139
3	1271.537	105.642 *	$1.15 imes 10^{-30}$ *	-45.313 *	-35.195	-41.541 *

* indicates lag order selected by the criterion; LR: sequential modified; FPE: final prediction error; AIC: Akaike information criterion; SC: Schwarz information criterion; HQ: Hannan–Quinn information criterion.

Based on the VAR estimations, we tested for Granger endogeneity using the Wald tests to examine the causal relationships among the variables, and all variables appear to be endogenous. The chi-square (Wald) statistics can be used to test the joint significance of each of the other lagged endogenous variables as well as for the joint significance of all other lagged endogenous variables. The test shows that the most significantly endogenous variable is women's labour participation, followed by physical capital formation and GNIP. The most exogenously determined variable is found to be women's participation in the national parliament, meaning that women's political empowerment is determined in an ad hoc manner according affiliation to political party and its agendas. Statistically speaking, however, this also means that women's political participation is the driving force of other variables. Results of Granger causality tests are reported in Appendix A, Table A1. Note that HIV is included as an explanatory variable on its own, and the dummy variable associated with it is included to account for the structural break in 1990.

The bounds test results confirm the existence of long-run equilibrium relationships between female human capital, its associated variables and real GNIP for both the ARDL and the NARDL models, as presented in Table 6.

ARE	DL (3, 0, 1, 2,	NARDL (3, 3, 3, 3, 1, 3, 3, 3, 0)				
F-Stat.		7.04			5.16	
Κ		8			8	
Critical Values	1%	2.5%	5%	1%	2.5%	5%
I(0)	2.62	2.33	2.11	2.62	2.33	2.11
I(1)	3.77	3.42	3.15	3.77	3.42	3.15

 Table 6. Bounds Test Results.

From Table 6, the NARDL produces a higher lag order than the ARDL, reflecting the longer time periods required for effects on the dependent variable to take place in the presence of structural breaks associated with the prevalence of HIV/AIDS. Given that long-run equilibrium relationships exist, the long-run and short-run dynamics of economic growth and female human capital and their co-variates are estimated for both ARDL and NARDL, and the results are presented in Table 7. Note that the results of the main ARDL and NARDL are summarized in Appendix A, Table A2.

Table 7. Long-Run ARDL and NARDL.

	ARDL (3, 0, 1,	2, 2, 0, 0, 2, 1)		NARDL (3, 3, 3, 3, 1, 3, 3, 3, 0)					
Variable	Coefficient	t-Sta.	Prob.	Variable	Coefficient	t-Sta.	Prob.		
L(FHC)	-11.08	-2.193	0.038 **	L(FHC)	-6.88	-2.873	0.013 ***		
L(LFF)	7.39	2.827	0.009 ***	L(LFF)	2.88	2.376	0.034 **		
L(PAW)	-0.74	-0.264	0.794	L(PAW)	7.07	3.205	0.007 ***		
L(AWR)	5.85	2.769	0.010 ***	L(AWR)	5.65	5.143	0.000 ***		
L(FER)	-5.30	-1.537	0.137	L(FER)	-12.82	-4.392	0.001 ***		
L(WPP)	-0.72	-1.729	0.096 *	L(WPP)	-1.16	-2.532	0.025 **		
L(FCF)	0.32	1.639	0.114	L(FCF)	0.57	3.603	0.003 ***		
HIV	-9.90	-3.011	0.006 ***	HIV	-5.59	-4.2430	0.001 ***		
С	66.15	2.430	0.023 **	С	19.68	1.812	0.093 *		
EC = L(GNIP)	P) - (-11.08 L(FHG))	C) + 7.39L(LFF)	- 0.74L(PAW)	EC = L(GNIP) - (-6.88L(FHC) + 2.88L(LFF) + 7.07L(PAW) +					
+5.85L(AWI	R) - 5.30L(FER) -	0.72L(WPP) +	0.32L(FCF) +	5.65L(AWR) - 12.82L(FER) - 1.16L(WPP) + 0.57L(FCF) +					
	9.90HIV	+ 66.15)		5.59HIV + 19.68)					

Note: Both ARDL and NARDL are Case 2: Restricted Constant and No Trend. ***, **, and * indicate significance at 1%, 5% and 10% level respectively.

Tables 7 and 8 read together show that female human capital has a negative effect on real GNIP in both models in the long and short runs, while fertility rate has the largest positive effect on real GNIP, followed by female labour participation in both the long and short runs. Women's political participation exerts a negative effect on real GNIP in the long run, while it has a positive effect on economic growth in the short run. Access to water in rural areas proves to have a sizable significant positive effect on GNIP in both the long run and the short run and in both models, ARDL and NARDL. The results also indicate that the lower the prevalence of anaemia among women, the higher the GNIP in the NARDL model. Physical capital has a positive effect on GNIP in the NARDL model, and this effect is more evident in the long run than in the short run. As expected, HIV prevalence exerts significant negative effects on GNIP on its own, especially in the ARDL model without breaks, in the long run more than in the short run.

	ARDL (3, 0, 1,	, 2, 2, 0, 0, 2, 1)		NARDL (3, 3, 3, 3, 1, 3, 3, 3, 0)				
Variable	Coefficient	t-Statistic	Prob.	Variable	Coefficient	t-Statistic	Prob.	
$\Delta L(GNIP)_{(t-1)}$	-0.31	-2.986	0.006 ***	$\Delta L(GNIP)_{(t-1)}$	-0.28	-3.055	0.009 ***	
$\Delta L(GNIP)_{(t-2)}$	-0.39	-4.074	0.000 ***	$\Delta L(GNIP)_{(t-2)}$	-0.38	-3.566	0.004 ***	
$\Delta L(LFF)$	-0.87	-5.071	0.000 ***	$\Delta L(FHC)$	-2.16	-5.063	0.000 ***	
$\Delta L(PAW)$	-0.31	-0.613	0.545	$\Delta L(FHC)_{(t-1)}$	-1.01	-2.492	0.027 **	
$\Delta L(PAW)_{(t-1)}$	-2.90	-4.558	0.000 ***	$\Delta L(FHC)_{(t-2)}$	-0.90	-2.204	0.046 **	
$\Delta L(AWR)$	0.65	1.781	0.087 *	$\Delta L(LFF)$	0.43	2.830	0.014 ***	
$\Delta L(AWR)_{(t-1)}$	-1.17	-3.350	0.003 **	$\Delta L(LFF)_{(t-1)}$	1.60	6.440	0.000 ***	
$\Delta L(FCF)$	-0.04	-2.451	0.022 **	$\Delta L(LFF)_{(t-2)}$	0.80	4.553	0.001 ***	
$\Delta L(FCF)_{(t-1)}$	-0.14	-6.860	0.000 ***	$\Delta L(PAW)$	0.46	0.923	0.373	
$\Delta(\text{HIV})$	1.26	5.027	0.000 ***	$\Delta L(PAW)_{(t-1)}$	-2.65	-4.736	0.000 ***	
$ECM_{(t-1)}$	-0.23	-9.784	0.000 ***	$\Delta L(PAW)_{(t-2)}$	-2.33	-3.530	0.004 ***	
· · · ·				$\Delta L(AWR)$	1.07	3.710	0.003 ***	
				$\Delta L(FER)$	1.07	0.769	0.456	
				$\Delta L(FER)_{(t-1)}$	6.30	4.271	0.001 ***	
				$\Delta L(FER)_{(t-2)}$	12.56	5.743	0.000 ***	
				$\Delta L(WPP)$	-0.47	-8.402	0.000 ***	
				$\Delta L(WPP)_{(t-1)}$	0.06	1.728	0.108	
				$\Delta L(WPP)_{(t-2)}$	0.10	2.612	0.022 **	
				$\Delta L(FCF)$	0.16	6.319	0.000 ***	
				$\Delta L(FCF)_{(t-1)}$	-0.04	-2.373	0.034 **	
				$\Delta L(FCF)_{(t-2)}$	-0.07	-3.827	0.002 ***	
				ΔHIV	-0.38	-8.625	0.000 ***	
				$ECM_{(t-1)}$	-0.41	-9.344	0.000 ***	
$R^2 = 0.83; Adj. I$	R2 = 0.77; SER =	= 0.028; SSR = 0.02	27; LL = 102.93;	$R^2 = 0.93; Adj. I$	R2 = 0.87; SER =	0.021; SSR = 0.01	l0; LL = 125.16;	
AIC = -4.8	36; SC = -3.645;	HQ = -3.922; D	.W. = 2.32	AIC = -4.5	541; SC = -3.617	; HQ = −4.196; D	D.W. = 2.61	
	Diag	nosis			Diag	nosis		
	χ 2 Norm. J-B =	= 1.13; P(0.566)		χ^2 Norm. J-B = 1.60; P(0.449)				
χ2 Ser	ial. LM, F = 2.24	l; P(0.147); D.W. =	= 2.06	χ 2 Serial. LM, F = 2.23; P(0.124); D.W. = 2.17				
χ2 H	letero. $F = 0.94;$	P(0.548); D.W. = 2	2.18	χ2 Hetero	o. $F = 2.57; P(0.3)$	35); P(0.182); D.V	V. = 2.57	
χ^2 Stability	y: CUSUM and	CUSUMQ; see Fi	igure 4a,b	χ^2 Stability	y: CUSUM and	CUSUMQ; see Fi	gure 4c,d	

Table 8. Short-Run Dynamics, ARDL and NARDL.

***, **, and * indicate significance at 1%, 5% and 10% level respectively.

From Table 8, the NARDL model fits the data better than the ARDL for GNIP model. Both the ARDL and the NARDL models are statistically significant and correctly adjusted to steady state equilibrium, but the NARDL performs better than the ARDL in terms of overall goodness of fit and with respect to individual parameters. The magnitudes of the ECM imply that the disequilibrium caused by a previous year's shocks converges back to the long-run equilibrium at the rate of 41% in the current year in the case of the NARDL, much higher than the rate of adjustment in the ARDL (23%). This may reflect how the prevalence of HIV among women disrupts their education and their health capital, which translated to a negative effect on real GNIP. An increase in the prevalence of HIV of 10% reduces income per capita by 38%. The significance of the ECMs provides additional evidence for the existence of a long-run equilibrium relationship between female human capital and economic growth in Sudan. The stability of the estimated ARDL and NARDL is ascertained as presented in Figure 4a,b and Figure 4c,d, the plots of the cumulative sum of the recursive residuals (CUSUM) and their squares (CUSUMQ), respectively, which all fall inside the critical bounds of 5% level of significance.



Figure 4. (a) ARDL CUSUM; (b) ARDL CUSUMQ; (c) NARDL CUSUM; (d) NARDL CUSUMQ.

5. Discussion

This study has investigated the role of female human capital and women's political participation in economic growth of Sudan. The study measured female human capital by women's health in terms of female life expectancy at birth from age 14 to age 64, which is the economically theoretically productive age and it contains women's fertility and reproductive years. Another variable used to measure female human capital is the gross enrolment of girls in primary education. Girls' completing primary education is crucial for their continuation to secondary and university education and for accumulation of their cognitive abilities. Female human capital, economic growth and their co-variables are found have long-run equilibrium relationships. The empirical findings of this study showed that female human capital has a negative effect on economic growth in Sudan, while fertility decline is found to have the largest and most positively significant effect on economic growth. Female labour and physical capital are found to have significant positive effects on economic growth, particularly in the long run.

The negative effect of female human capital in terms of educational attainment could be due to the low cognitive abilities of the educated girls, akin to what has been documented by Ozawa et al. [79] in low- and middle-income countries. It could also be due to low adjusted life expectancy at birth for women and its implications for their economically productive and biologically reproductive life spans. Furthermore, the negative effect is most likely be due to the underestimated prevalence of HIV/AIDS, which is found by itself to exert a negative and significant effect on economic growth, especially when structural breaks are taken into account in the case of the NARDL model. In fact, Elsiddig et al. [80] in a sample study documented that more than 90% of children infected with HIV in Sudan had been infected via mother-to-child transmission, which clearly affects girls' enrolment in schools and their health capital. The positive effects of women's political participation and physical capital formation on female labour force participation from the VAR model confirms the role

of these variables in women's empowerment as documented by Varghese [81] in the case of Oman.

Reduced prevalence of anaemia among women of ages 14–64 and, conversely, increased access to drinking water in rural areas are found to have sizable positive and significant effects on economic growth, particularly in the long run. Women's empowerment in terms of political participation in the parliament is found to have a positive and significant effect on economic growth in the short run only. The non-existence of a positive effect of women's political participation on economic growth in the long run could be due to the low competencies of the selected women, which has historically been based upon political party affiliation and not on women's merits and leadership qualities, which make parliamentary women contribute little to gender equality and women's democratic rights, as documented in [30,31] in Sudan and in [34] across African countries. More importantly, it is evident from the results of this study that women's employment is of huge importance to economic growth in Sudan regardless of their human capital endowment. In this regard, the gap in women's vulnerability in employment compared with that of men, as well as the gap in the waged and salaried formal sectors, should be addressed and reduced.

Overall, there are urgent needs for relevant government policies to be designed and directed with a plan vision of a virtuous circle in making productive use of the resources possessed by the poor, including women, i.e., their labour, through investments in quantity and quality education, especially in presence of natural resource abundance, as suggested by [82] based on evidence of growth success and failure in other countries. Women's economic and political empowerment and Sudan's WID should be objectively assessed far from the narrow partisan perspective and beyond the mainstream women's political rights movement and gender-centred debates. HIV programmes for women health and life should be evaluated beyond international donors reports.

6. Conclusions

Female human capital formation and utilization is a major determinant of economic growth in Sudan. In light of this study's findings, women's economic and political empowerment should be based on a holistic WID perspective, based on women's education and political competencies, for the effective promotion of women's economic and political status. As this study is based on national average data, regional and rural–urban female human capital and political participation deserve special investigation. The prevalence and effects of HIV/AIDs among women by region, education level and residence setting requires further empirical cross-sectional and time-series investigation with the genuine assessment of prevention and treatment programmes.

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Appendix A

Dependent	Excluded	Chi-sq	df	Prob.	Dependent	Excluded	Chi-sq	Df	Prob.
	L(FHC)	4.33	2	0.115		L(GNIP)	2.83	2	0.243
	L(LFF)	3.19	2	0.203		L(LFF)	0.47	2	0.791
	L(PAW)	4.94	2	0.085 *		L(PAW)	1.57	2	0.457
	L(AWR)	7.82	2	0.020 **		L(AWR)	3.17	2	0.205
L(GNIP)	L(FER)	2.68	2	0.262	L(FHC)	L(FER)	3.74	2	0.154
	L(WPP)	1.73	2	0.422		L(WPP)	0.90	2	0.637
	L(FCF)	1.35	2	0.509		L(FCF)	0.86	2	0.651
	HIV	2.47	2	0.291		HIV	1.54	2	0.462
	All	41.52	16	0.001 ***		All	20.86	16	0.184
	L(GNIP)	0.26	2	0.877		L(GNIP)	0.16	2	0.921
	L(FHC)	0.85	2	0.655		L(FHC)	0.04	2	0.978
	L(PAW)	0.76	2	0.683		L(LFF)	1.36	2	0.508
	L(AWR)	2.02	2	0.365		L(AWR)	1.24	2	0.539
L(LFF)	L(FER)	9.87	2	0.007 ***	L(PAW)	L(FER)	2.62	2	0.269
	L(WPP)	18.91	2	0.000 ***		L(WPP)	0.14	2	0.930
	L(FCF)	3.80	2	0.149		L(FCF)	0.15	2	0.928
	HIV	9.70	2	0.008 ***		HIV	1.05	2	0.590
	All	36.89	16	0.002 ***		All	20.53	16	0.198
	L(GNIP)	6.65	2	0.036 **		L(GNIP)	1.28	2	0.526
	L(FHC)	0.63	2	0.731		L(FHC)	0.64	2	0.724
	L(LFF)	1.29	2	0.524		L(LFF)	7.81	2	0.020 **
	L(PAW)	11.51	2	0.003 ***		L(PAW)	0.80	2	0.671
L(AWR)	L(FER)	1.49	2	0.474	L(FER)	L(AWR)	1.95	2	0.377
	L(WPP)	1.35	2	0.510		L(WPP)	2.76	2	0.252
	L(FCF)	2.19	2	0.335		L(FCF)	0.54	2	0.764
	HIV	4.64	2	0.098 *		HIV	0.61	2	0.739
	All	26.85	16	0.043 **		All	32.33	16	0.010 ***
	L(GNIP)	1.20	2	0.548		L(GNIP)	0.65	2	0.722
	L(FHC)	3.80	2	0.150		L(FHC)	0.69	2	0.708
	L(LFF)	0.39	2	0.824		L(LFF)	6.51	2	0.039 **
	L(PAW)	2.78	2	0.249		L(PAW)	6.89	2	0.032 **
L(WPP)	L(AWR)	3.97	2	0.137	L(FCF)	L(AWR)	4.80	2	0.091 *
	L(FER)	0.43	2	0.805		L(FER)	14.95	2	0.001 **
	L(FCF)	1.18	2	0.556		L(WPP)	3.00	2	0.224
	HIV	0.30	2	0.863		HIV	3.61	2	0.165
	All	23.28	16	0.106		All	62.89	16	0.000 ***
	L(GNIP)	3.91	2	0.142					
	L(FHC)	1.85	2	0.396					
	L(LFF)	0.24	2	0.889					
	L(PAW)	4.73	2	0.094 *					
HIV	L(AWR)	12.71	2	0.002 ***					
	L(FER)	3.64	2	0.162					
	L(WPP)	6.72	2	0.035 **					
	L(FCF)	12.20	2	0.002 ***					
	All	34.35	16	0.005 ***					

 Table A1. Granger Causality, Wald Tests.

***,**, and * indicates significant at 1%, 5% and 10% level respectively.

	ARDL (3, 0, 1,	2, 2, 0, 0, 2, 1)		NARDL (3, 3, 3, 3, 1, 3, 3, 3, 0)				
Variable	Coefficient	t-Statistic	Prob.	Variable	Coefficient	t-Statistic	Prob.	
$L(GNIP)_{(t-1)}$	0.47	3.327	0.003 ***	$L(GNIP)_{(t-1)}$	0.30	1.423	0.178	
$L(GNIP)_{(t-2)}$	-0.08	-0.460	0.649	$L(GNIP)_{(t-2)}$	-0.09	-0.427	0.676	
$L(GNIP)_{(t-3)}$	0.39	2.562	0.017 **	$L(GNIP)_{(t-3)}$	0.38	2.161	0.050 **	
L(FHC)	-2.53	-4.877	0.000 ***	L(FHC)	-2.156	-2.391	0.033 **	
L(LFF)	-0.87	-2.860	0.008 ***	$L(FHC)_{(t-1)}$	-1.706	-1.439	0.174	
$L(LFF)_{(t-1)}$	-0.82	-3.512	0.002 ***	$L(FHC)_{(t-2)}$	0.11	0.130	0.898	
L(PAW)	-0.31	-0.439	0.664	$L(FHC)_{(t-3)}$	0.90	1.178	0.260	
$L(PAW)_{(t-1)}$	-2.75	-2.250	0.034 **	L(LFF)	0.43	1.135	0.277	
$L(PAW)_{(t-2)}$	2.89	3.081	0.005 ***	$L(LFF)_{(t-1)}$	-0.02	-0.081	0.936	
L(AWR)	0.65	0.885	0.385	$L(LFF)_{(t-2)}$	-0.80	-2.363	0.034 **	
$L(AWR)_{(t-1)}$	-0.49	-0.605	0.551	$L(LFF)_{(t-3)}$	-0.80	-2.107	0.055 *	
$L(AWR)_{(t-2)}$	1.17	1.740	0.094 *	L(PAW)	0.46	0.537	0.601	
L(FER)	-1.21	-2.668	0.013 ***	$L(PAW)_{(t-1)}$	-0.18	-0.143	0.889	
L(WPP)	-0.16	-2.281	0.031 **	$L(PAW)_{(t-2)}$	0.32	0.252	0.805	
L(FCF)	-0.04	-1.400	0.174	$L(PAW)_{(t-3)}$	2.33	1.728	0.108 *	
$L(FCF)_{(t-1)}$	-0.03	-1.300	0.206	L(AWR)	1.07	1.303	0.215	
$L(FCF)_{(t-2)}$	0.14	4.744	0.000 ***	$L(AWR)_{(t-1)}$	1.27	1.030	0.322	
HIV	1.26	2.861	0.008 ***	L(FER)	1.07	0.368	0.719	
$HIV_{(t-1)}$	-1.00	-2.925	0.007 ***	$L(FER)_{(t-1)}$	-0.08	-0.023	0.982	
Ċ	15.09	3.507	0.002 ***	$L(FER)_{(t-2)}$	6.26	1.596	0.135	
				$L(FER)_{(t-3)}$	-12.56	-2.928	0.012 ***	
				L(WPP)	-0.47	-4.299	0.001 ***	
				$L(WPP)_{(t-1)}$	0.05	0.640	0.533	
				$L(WPP)_{(t-2)}$	0.04	0.525	0.608	
				$L(WPP)_{(t-3)}$	-0.10	-1.413	0.181	
				L(FCF)	0.16	2.635	0.021 **	
				$L(FCF)_{(t-1)}$	0.04	1.176	0.261	
				$L(FCF)_{(t-2)}$	-0.03	-0.740	0.473	
				$L(FCF)_{(t-3)}$	0.07	1.991	0.068 *	
				HIV	2.31	4.157	0.001 ***	
				DHIV	-0.58	-4.534	0.001 ***	
_				С	8.15	2.011	0.066 *	
$R^2 = 0.99; Adj. I$	R = 0.99; SER = 0	.033; SSR = 0.027	; LL = 102.94; F.	$R^2 = 0.99; Adj.$	R = 0.99; SER = 0	.028; SSR = 0.010	; LL = 125.16; F.	
Stat. = 283.61	l, P(0.000); AIC =	= -3.686; SC = -1	2.882; HQ =	Stat. = 243.41, P(0.000); AIC = -4.142; SC = -2.856; HQ =				
	-3.387; D	.W. = 2.32			-3.662; D	.W. = 2.61		

Table A2. Main ARDL and NADRL Models.

***, **, and * indicate significance at 1%, 5% and 10% level respectively.

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