EXTENDED ABSTRACT

Human Capital and Labor Productivity: Policy Implications of Changing Age-Structures in Five Sub-Saharan African Countries

Marlene Lee
Population Reference Bureau

Joshua Wilde
Max Planck Institute for Demographic Research

and

Mahesh Karra
Boston University

PRELIMINARY ANALYSIS - PLEASE DO NOT CITE

Acknowledgements: The authors would like to acknowledge the able research assistance of Aimee Rivera and Vida Chea and suggestions from Ishrat Husain and Kaitlyn Patierno.

ABSTRACT

The Canning-Karra-Wilde (CKW) model explicitly incorporates age-structure change into dynamics of the economic production function and simulates economic output under high fertility and endogenous low-fertility regimes (Karra, Canning, & Wilde, 2017). In this paper, we take advantage of the human capital adjustment that is included in the model's structure to show the trajectory of labor productivity over time under these scenarios. We use the model to quantify the cost of failure to adequately invest in education during the age-restructuring of the population. Finally, we consider, relative to estimated economic growth and in light of digital technologies showing promise for African countries, the cost of community health programs that could produce the endogenous low-fertility scenario. Our paper demonstrates the usefulness of the CKW model in illustrating the effects of policy levers inherent in the model's underlying economic production function and contributes to better understanding specifications of age-structure change in demographic dividend models. [149 Words]

BACKGROUND

In high-fertility countries, when women and couples with unmet contraceptive needs are able to access high quality family planning and reproductive health services, fertility can decline rapidly. Such fertility decline leads to changes in age structure that open a demographic window of opportunity for faster economic growth. Using this opportunity to a country's advantage requires additional investments in women and children.

The Canning-Karra-Wilde (CKW) model provides a rigorous tool for assessing the potential impact of a successful community-based family planning program on economic growth over time and the impact of investments in children (Karra et al., 2017). We use the CKW model to estimate aggregate output under two scenarios for five countries: Ghana, Kenya, Nigeria, Uganda, and Zimbabwe. It allows us to investigate the potential effect of an intensive community-based family planning and maternal child health program on economic growth and development outcomes such as education, women's labor force participation, labor productivity, and capital accumulation.

Designed specifically to consider economic production and fertility dynamics in sub-Saharan Africa's high-fertility countries, the model is a macrosimulation of how much extra output is generated as fertility falls over a specific time horizon. The simulation uses two scenarios: one based on the UN high fertility variant and a low endogenous fertility variant based on slowly declining fertility. The mortality inputs (declining age-specific mortality rates over time) are a constant across the scenarios. Sex ratios in both scenarios follow the UN projections of sex ratios at birth and over time. The difference between these two variants closely parallels the aggregate shift in fertility experienced resulting from the community-based intervention in Matlab, Bangladesh, with a 0.8 decline in average births per woman after ten years. This simulation approach, with inputs and parameters based on economic theory and microeconomic evidence, traces the dynamic evolution of population age structure, accumulation of physical and human capital, and natural resource congestion.

The model has a three-sector economy: a highly productive modern sector that uses physical capital, human capital, and labor; a traditional sector that uses land and labor (e.g. subsistence agriculture or other labor-intensive informal economies); and a raw material sector that requires no domestic inputs (may require foreign funds and labor). It assumes age-specific male participation rates fixed at the initial input level over time. The age-specific female labor force participation rates in each five-year period change in response to fertility decline, following estimates of women's substitution between childcare and work. The section that follows elaborates the production function that models economic development where only two of the three sectors use domestic labor and capital. These are most pertinent to our discussion of human capital, labor productivity, and effects of changing age structure.[1]

ECONOMIC DEVELOPMENT THREE SECTOR MODEL

Production

The Canning-Karra-Wilde (CKW) model simulates country output over time using a Lewis development economy with three sectors: a modern sector, a traditional/subsistence sector, and a raw materials sector, where modern and traditional sectors share the total labor supply across sectors to produce distinct commodities. The economy's total output is the sum of output in all three sectors. The model holds the value of the raw materials sector constant. In the CKW model, aggregate production in the modern and traditional sectors is given by standard Cobb-Douglas production functions that are specified for each sector. Output in the modern sector, m, is a function of K, physical capital, and L, labor (either raw labor or adjusted for human capital), while output in the traditional sector, a, is a function of labor and N_a, a non-renewable resource such as arable land:

$$Y_{a,t} = A_{a,t} \cdot F\left(L_{a,t}, N_a\right)$$

$$Y_{m,t} = A_{m,t} \cdot F\left(K_{m,t}, L_{m,t}\right)\bar{A}$$

$$A_{j,t} = \bar{A}\exp\left(\lambda_j, t\right)$$

with sectors $j = a, m$ so that a is traditional and m is modern.

A represents the proportion of outputs not explained by inputs (K, L, N) and is thus an indicator of how efficiently and intensively inputs are utilized. In the general specification, A or total factor productivity (TFP), has a growth rate of λ with the initial TFP level varying by sector. TFP at later points in time depends on the share of labor in that sector.

Further developing the three equations above, in the modern sector function, labor input is adjusted for human capital as measured by education and health indicators. The traditional sector function uses raw labor input.

$$Y_{m,t} = \bar{A}_m K_{m,t}^{1-\alpha} L_{m,t}^{\alpha} \exp(\gamma \cdot E_t + \varepsilon \cdot H_t)$$

where γ is the return to education and ε is the return to health

$$Y_{a,t} = \bar{A} N_a^{1-\beta} L_{a,t}^{\beta}$$

[1]The full elaboration of the CKW specification for population growth, labor supply, capital accumulation and savings, labor allocation across sectors may be found in appendices to Karra, Canning, & Wilde (2017) online.

The change in output associated with small changes in physical capital or labor is *the marginal product* of capital or of labor, respectively. For the Cobb-Douglas production function, the marginal product of labor is the average product of labor multiplied by a constant. The marginal product of labor by sector from the CKW model is:

$$\frac{\partial Y_{m,t}}{\partial L_{m,t}} = \alpha \cdot \bar{A}_m K_{m,t}^{1-\alpha} L_{m,t}^{\alpha-1} \exp(\gamma \cdot E_t + \varepsilon \cdot H_t) = \frac{\alpha Y_{m,t}}{L_{m,t}}$$

$$\frac{\partial Y_{a,t}}{\partial L_{a,t}} = \beta \cdot \bar{A} N_a^{1-\beta} L_{a,t}^{\beta-1} = \frac{\beta Y_{a,t}}{L_{a,t}}$$

Similarly, the marginal product of K in the modern sector is:

$$\frac{\partial Y_{m,t}}{\partial K_{m,t}} = (1-\alpha) \cdot \bar{A}_m K_{m,t}^{-\alpha} L_{m,t}^{\alpha} \exp(\gamma \cdot E_t + \varepsilon \cdot H_t) = \frac{(1-\alpha) Y_{m,t}}{K_{m,t}}$$

Similarly, the marginal product of N_a in the agricultural sector is:

$$\frac{\partial Y_{a,t}}{\partial N_a} = (1-\beta) \cdot \bar{A} N_a^{-\beta} L_{a,t}^{\beta} = \frac{(1-\beta) Y_{a,t}}{N_a}$$

Aggregate output changes with increases in total factor productivity would be:

$$\frac{\partial Y_{a,t}}{\partial A_{a,t}} = \frac{Y_{a,t}}{A_{a,t}}$$

Persistent and significant TFP level differences between sectors signal the presence of barriers to technology acquisition or some other form of friction in the low-TFP sector (Eberhardt & Teal, 2010). Thus changes in TFP would be expected from investments in technology. Empirically, traditional agriculture tends to have lower TFP than the modern sector.

There are public policy implications from these formulas.

A one percent increase in L increases output in the modern sector by "α" percent and output in the traditional sector by "β" percent, where alpha and beta greater than zero less than one. With a one percent increase in K, output in the modern sector increases by "$1-\alpha$" and in the traditional sector by "$1-\beta$". And a one percent increase in TFP increases output by one percent. Thus, if public policies are being considered to stimulate the growth of real output, one needs to take the "exponents" of capital and labor into account in assessing the relative impacts of policies on the growth of inputs or the impacts of total factor productivity on the subsequent growth of real output.

The functional form of marginal product of labor (MPL) has diminishing returns to labor, whereby increases in labor decreases MPL. In theory, in competitive economies, in the modern sector, the real wages paid to labor equals MPL. Firms cannot make a profit if they pay more than MPL. Wages paid in the traditional agricultural sector are equal to average product of labor. Both have implications for the effect of population growth on wages.

Theoretically, if agricultural labor inputs increase agricultural outputs very little beyond a certain level of production, then the addition of workers beyond this point will push wages down. If wages fall below subsistence level in the traditional agricultural sector, then additional workers (even family members working for household consumption) cannot be sustained. Nonetheless, cultural norms surrounding the institution of family mean that in traditional agricultural economies family workers might continue work on family land even though their labor does not actually increase aggregate output by as much as they consume. Traditional sectors can hide labor and buffer the transition to a modern industrial economy. Population growth can also mean that competition for jobs keeps wages low in the modern sector. It is important to continue to invest in traditional sectors as well as modern industries. For example, food scarcity could inhibit the growth of the modern sector because it affects the health of workers. Also, failure to invest in a traditional sector such as agriculture may hasten the exodus from these traditional jobs beyond the ability of job creation in the modern sector to absorb labor. Finally, investment in technology could boost aggregate output from the agricultural sector or another traditional sector even as labor migrates to the modern sector.

The CKW model assumes equilibrium in the labor market, that is no unemployment and wages equal to marginal product, such that workers will move freely between sectors until wages are equalized across sectors. With respect to capital, the CKW model assumes the country's economy is closed to international capital flows. Equilibrium in the labor market means that the model estimates optimal output.

<u>Human Capital</u>

In this CKW model, labor inputs are adjusted for human capital as measured by indicators of education and health. Both the high fertility and low endogenous fertility scenarios estimated with the model assume no changes in returns to education or returns to health over time.

In the Karra et al. (2017) analysis, the pace of change in age-specific fertility over time is the only difference between the two scenarios. This difference in pace affects the age distribution of the labor force, accumulation of human capital in the workforce, marginal product of labor, and ultimately, real output. The pace of change in the second scenario is a result of both the lower fertility schedule by age and the endogenous relationship between fertility and education. Education increases as fertility rates decrease, and an increase in education decreases fertility rates.

The CKW model estimates average education of the workforce at time t as the weighted sum of sex-specific average levels of schooling divided by total labor supply:

$$E_t = \frac{\left(E_{f,t} \cdot L_{f,t} + E_{o,t} \cdot L_{o,t}\right)}{L_{f,t} + L_{o,t}}$$

where f is female and o is male.

Karra et al. (2017) consider the workforce to be comprised of nine cohorts defined by five-year age groups from age 20 through age 64. Sex-specific average education of the workforce is calculated from the sex-specific average education of each cohort i:

$$E_{f,t} = \sum_{i=1}^{9} E_{f,it}\left(\frac{L_{f,it}}{L_{f,t}}\right)$$

where $i = (20-24, 25-29, \ldots, 60-64)$

The above equations make it clear that aggregate average education depends on the age distribution of the workforce and education attainment within each cohort.

In the high fertility scenario, the authors treat education as exogenous and calculate it from extant data. In the low fertility scenario, education is endogenous: Average education of the female and male age cohorts ($E_{f,it}$ and $E_{o,it}$, respectively) in the workforce at time t depends on fertility through the parameter θ_E, which is assumed to be positive and captures the effect of fertility on children's education. θ_E is weighted by average education of the cohort at age 20-24, from the high fertility variant which uses exogenous education ($E_{f,1t}$ and $E_{o,1t}$, respectively). Thus, in the low fertility endogenous variant:

$$E_{f,it} = E_{f,i-1,t-1} = E_{f,1t}$$

for all $i > 1$, i.e after age 20-24.

Letting $E^*_{f,1t}$ be the average education of the age 20-24 cohort at time *t* under the high fertility variant, then $E_{f,it}$ *and* $E_{o,it}$ are functions of $E^*_{f,1t}$ and θ_E and total fertility rates (TFR) [2]:

$$E_{f,it} = E^*_{f,1t}[1 - \theta_E(TFR^*_{i+4} - TFR_{i+4})]$$

Combining equations above:

$$E_t = \frac{[1 - \theta_E(TFR^*_{i+4} - TFR_{i+4})] \sum_{i=1}^{9} E^*_{f,1t} L_{f,it} + E^*_{o,1t} L_{o,it}}{L_{f,t} + L_{o,t}}$$

The equations that describe the relationship of fertility and health mirror the equations above that describe the relationship of fertility and education. θ_H is an exogenous constant that captures the direct effect of fertility on our health indicator, adult height.

The policy implication is that even with investments in a community health program that lowers fertility, investments in education and health must be sufficient to maintain the returns to education and health assumed in the model. The model values used come from empirical estimates of average returns. We estimate models with below average returns to education to demonstrate how much lower real output would be. These lower returns to education and health essentially lower the labor productivity. We interpret lower returns to education as less effective years of education which could be a mismatch of training and skills demanded.

DATA

Our analysis updates the population and fertility data used in the CKW model, using the 2019 edition of the UN World Population Prospects. We use the country-specific labor force participation rates from the ILOSTAT database and conducted literature searches to identify country-specific estimates for returns to education.

---

[2]Karra et al. (2017) provided supplemental appendices and provide the equation below. However, the equation in the appendix has an error in notation and is given as: $E_{f,it} = E^*_{f,1t}[1 + \theta_E(TFR^*_{t-4} - TFR_{t-4})]$. The estimates in Karra et al. (2017) are correctly calculated despite the notation error.

DISCUSSION

Our additions to the CKW model analysis from Karra et al. (2017) allow us to discuss the policy impact of coordinating investments in community-based family planning programs, education suited to labor market opportunities, and sector-specific production enhancing technology.

REFERENCES

Eberhardt, M., & Teal, F. (2010). *Growth and Development in an Empirical Dual Economy Model*.

Karra, M., Canning, D., & Wilde, J. (2017). The Effect of Fertility Decline on Economic Growth in Africa: A Macrosimulation Model. *Population and Development Review*, *43*(S1), 237–263. https://doi.org/10.1111/padr.12009

Peet, E., etal. (2015). Returns to Education in Developing Countries: Evidence from the Living Standards and Measurement Study Surveys, Economics of Education Review, 49, 69-90.

PRELIMINARY RESULTS – TABLES AND FIGURES

Table 1 – Model Fertility Rates

	Initial Value	**High Variant(a)**	**Low Endogenous(b)**	**Most Recent Estimate (c)**
	2010-2015	*After 20 years*	*After 20 years*	*2017*
Ghana	**4.25**	**3.46**	**2.12**	**3.9**
Kenya	**4.44**	**3.84**	**2.76**	**3.8**
Nigeria	**5.74**	**4.92**	**3.83**	**5.5**
Uganda	**5.91**	**4.75**	**3.65**	**5.5**
Zambia	**5.45**	**4.84**	**3.74**	**4.9**

Source: (a) 2015 Version of UN Population Estimates and Projections; (b) Model estimates; (c) World Bank

Note: Total fertility rate represents the number of children that would be born to a woman if she were to live to the end of her childbearing years and bear children in accordance with age-specific fertility rates of the specified year.

Table 2 – Estimated Returns to Education for Selected Countries

COUNTRY	AVERAGE RETURN TO EDUCATION	LOW END OF CONFIDENCE INTERVAL (95%)	HIGH END OF CONFIDENCE INTERVAL (95%)
COTE D'IVOIRE	6.83%	6.08%	7.57%
ETHIOPIA	12.54%	9.93%	15.15%
GHANA	4.20%	3.92%	4.48%
KENYA			
MALAWI	12.14%	11.47%	12.81%
NIGER	11.10%	9.90%	12.30%
NIGERIA	5.62%	5.16%	6.08%
SOUTH AFRICA	10.74%	10.31%	11.18%
TANZANIA	10.97%	9.64%	12.29%
UGANDA	11.94%	11.27%	12.62%
ZAMBIA			
REGIONAL SUBTOTAL (AFRICA)	9.52%	7.06%	11.97%

Source: Peet etal, 2105. *Economics of Education Review*

Note: Estimates for Kenya and Zambia not available in this analysis

Figure 1 – Example of Fertility Decline from Model, Zambia

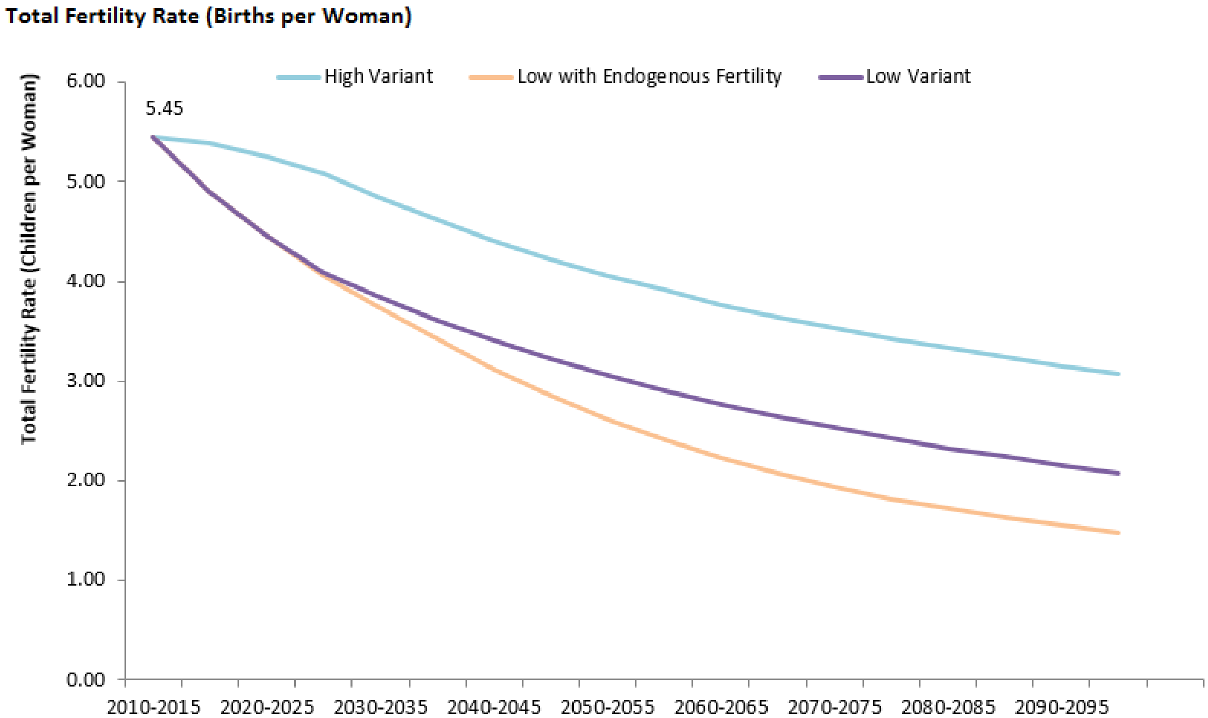
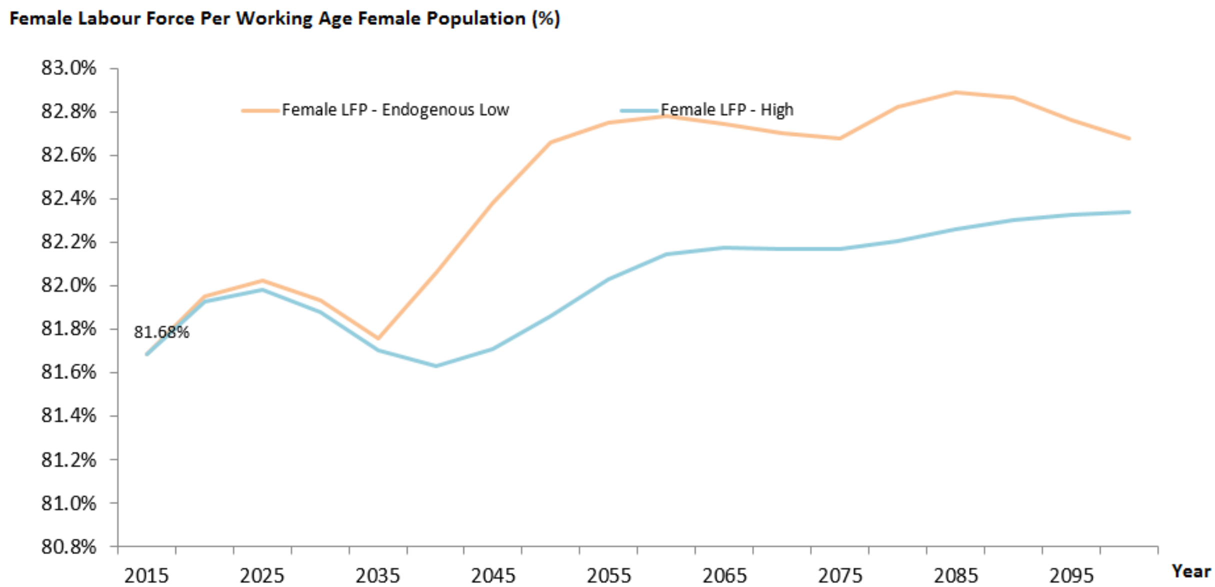


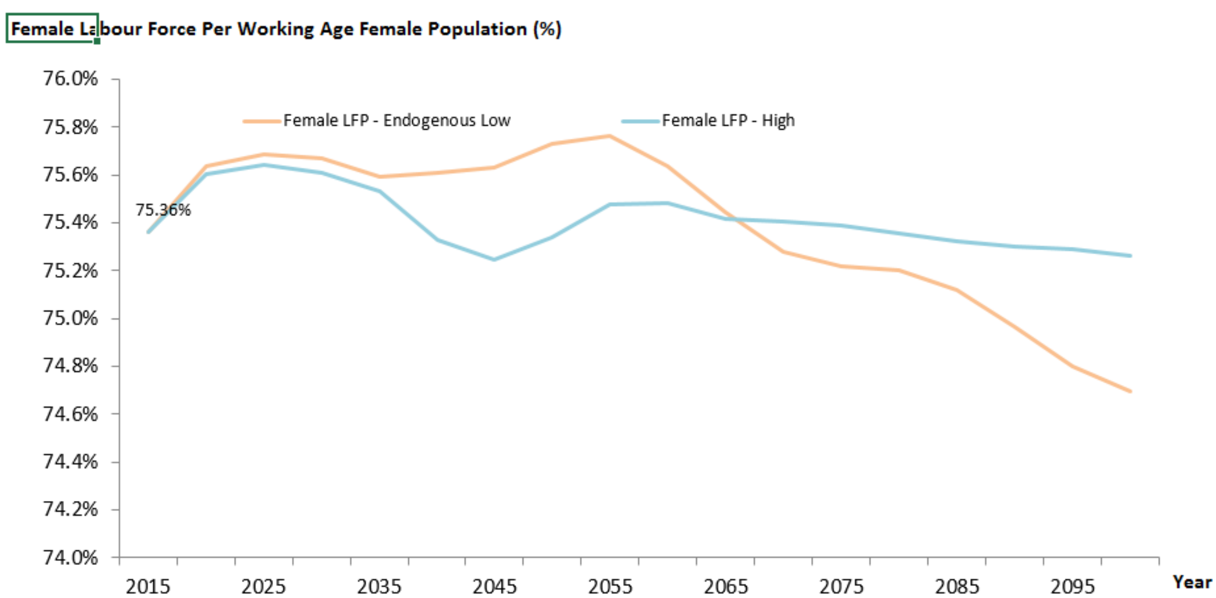
Figure 2 – Comparison of Female Labor Force Participation Rates Under 2 Fertility Scenarios

[Note: Returns to education set to 10% (African Mean)]

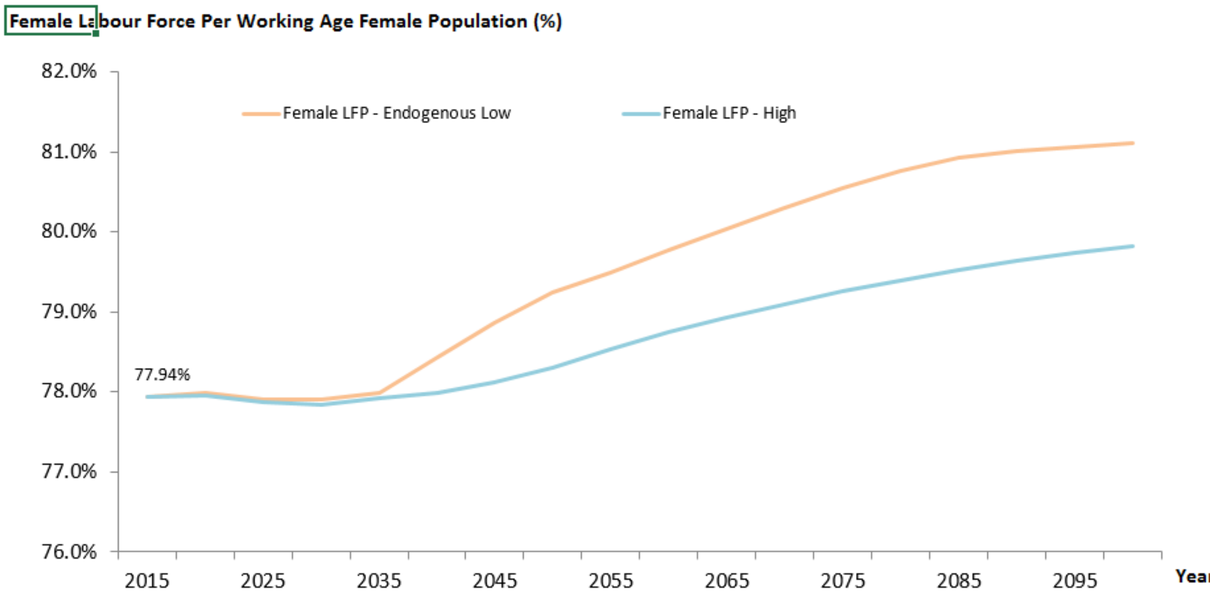
A. Ghana



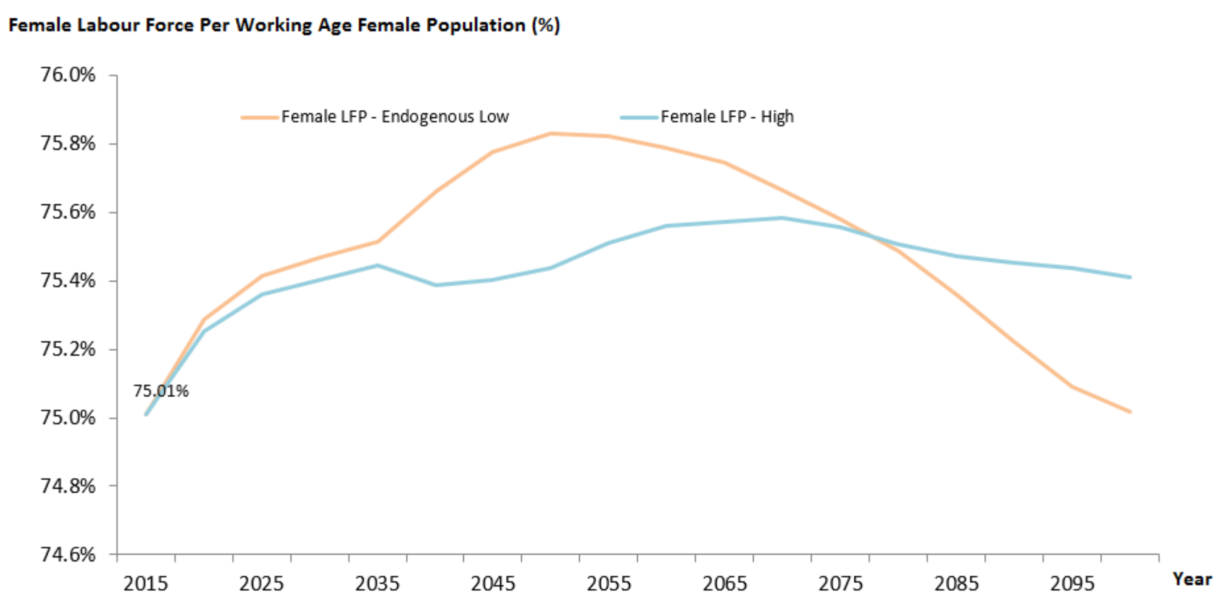
B. Kenya



C. Nigeria



D. Uganda



E. Zambia

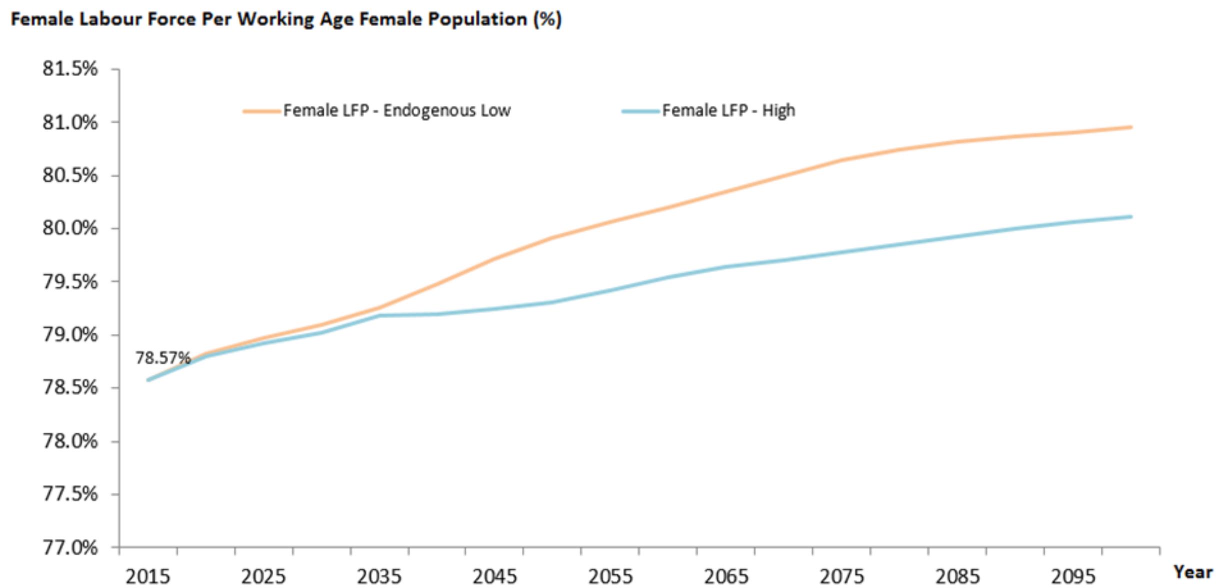

Female Labour Force Per Working Age Female Population (%)
81.5%
81.0%
80.5%
80.0%
79.5%
79.0%
78.5%
78.0%
77.5%
77.0%
Female LFP - Endogenous Low
Female LFP - High
78.57%
2015
2025
2035
2045
2055
2065
2075
2085
2095
Year

Table 2. Human Capital Index

A. Ghana

	Human Capital Index - Ghana																	
Year	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
Low Variant	100	104.13	108.83	113.81	118.77	123.33	127.48	131.24	134.73	138.28	141.25	143.85	146.22	148.60	150.91	153.15	155.28	157.29
High Variant	100	103.03	105.76	108.30	110.99	113.83	116.67	119.29	121.66	124.07	126.47	128.82	131.09	133.21	135.19	137.03	138.75	140.33

B. Kenya

	Human Capital Index - Kenya																	
Year	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
Low Variant	100.00	102.82	106.33	109.96	112.97	115.41	117.57	120.33	123.60	127.63	131.13	134.27	137.17	140.09	142.94	145.71	148.30	150.71
High Variant	100.00	101.36	102.50	103.57	104.72	106.00	107.36	109.28	111.56	114.42	117.28	120.09	122.81	125.34	127.71	129.92	131.95	133.81

C. Nigeria

	Human Capital Index - Nigeria																	
Year	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
Low Variant	100.00	104.37	109.54	115.21	120.54	125.42	130.34	135.70	141.52	147.78	153.64	159.16	164.36	169.36	174.00	178.35	182.39	186.19
High Variant	100.00	102.98	105.69	108.48	111.41	114.71	118.55	122.94	127.63	132.59	137.60	142.50	147.20	151.53	155.52	159.19	162.54	165.60

D. Uganda

	Human Capital Index - Uganda																	
Year	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
Low Variant	100.00	104.12	109.27	114.90	120.27	125.23	130.55	135.97	141.89	147.83	153.17	158.01	162.41	166.61	170.55	174.19	177.52	180.56
High Variant	100.00	102.66	105.52	108.69	112.26	116.17	120.72	125.31	130.11	134.79	139.32	143.63	147.64	151.28	154.60	157.60	160.32	162.77

E. Zambia

	Human Capital Index - Zambia																	
Year	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
Low Variant	100.00	100.11	101.26	102.86	104.41	105.95	107.73	110.03	113.39	117.54	121.29	124.63	127.73	130.85	133.94	136.91	139.70	142.33
High Variant	100.00	98.60	97.48	96.85	97.05	97.94	99.36	101.22	103.77	106.84	109.97	113.05	116.04	118.81	121.44	123.91	126.23	128.41