Savings and the Demographic Dividend: Evidence from a Macrosimulation Model

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Abstract: In the Demographic Dividend literature, a large proportion of the theoretical benefit to reducing fertility rates is typically attributed to increased savings by families with fewer children, which in turn leads to higher investment and increased formation of productive capital. However, the evidence on the magnitude of the effect of reduced fertility on savings rates and on the extent to which those savings are translated into subsequent investment, which directly speaks to the importance of this key theoretical channel, is unclear. In this study, we use a recent macrosimulation model from Karra, Canning, and Wilde (2017) to estimate the overall effect of savings under a range of commonly used savings and investment assumptions. We find that changes in savings only contributes greatly to the Demographic Dividend under few, and likely unrealistic, modeling assumptions, thereby implying that caution is warranted when using increased savings as a central rationale for promoting fertility decline.

Keywords: Savings, Demographic Dividend, Fertility, Sub Saharan Africa, Macrosimulation

JEL codes: J11, J13, O11, O21, O4.

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I Introduction

The Demographic Dividend, which characterizes the effects of demographic transitions and changes in population age structure on economic growth and development, has been the subject of considerable interest to academics, policymakers, and practitioners in recent decades. The economic impact of the Demographic Dividend, particularly on growth in per capita income, has been extensively studied in the U.S. [35], East Asia [6, 28], Egypt [5], and many other countries around the world [22,24]. Recent work by the Health Policy Plus Project [31], Ashraf, Weil, and Wilde (2013) [2], Mason and Lee (2004), and Karra, Canning, and Wilde (2017) [20], among others, have identified and explored some of the key channels through which the Demographic Dividend has operated, including the role of population change on human capital (health, education), female labor force participation, and productivity.

In addition to these channels, several studies have also theorized the role of capital accumulation and savings, which are widely believed to be main drivers of the Demographic Dividend. Given that savings rates at the household level vary with age, peaking during the working-age period of the life cycle, aggregate savings at the national level will depend on the age structure of the population, particularly the dependency ratio [4,17,25,26]. The literature has also identified an additional effect of lower fertility on expected transfers from children to their elderly parents, which would increase the need for savings for retirement [38, 40]. Finally, higher savings rates from fertility decline may result in increases in capital intensity (capital deepening) that are larger than the effect from having smaller cohorts of working-age people [20, 37].

While the theoretical role of savings has been widely discussed in the literature, many of the assumptions of the economic effects of demographically-induced changes in savings have not been tested with data, and existing evidence of the role of savings is limited; as a result, there is a growing concern that the relatively prominent role of population-driven savings on growth may not be empirically supported, particularly in low- and middle-income settings where savings rates are low [21, 36]. Many studies have typically assumed that all new "available" income will be saved; this is contrary to economic theories of the permanent income hypothesis, which stipulates that the choice of whether new income is saved or consumed depends on the extent to which the change in new income is permanent or transitory. In this regard, changes in income per capita from having fewer children are likely to be shocks to permanent income, which would imply that little income would be saved as a result [1, 14, 30, 36]. In addition, the literature on the theoretical role of savings on growth is couched in the savings-investment identity, which stipulates that aggregate savings is equivalent to aggregate investment (Abel, Bernanke, and Croushore 2017). In high-income settings, however, the empirical relationship between savings and investment is weak due to the open economy structure whereby international trade flows drive both savings and investment behaviors (see Figure 1 from Penn World Tables). On the other hand, the equivalency of the savings-investment identity may be more suited for lower-income settings, where international capital flows play a more limited role. Even if assuming a savings-investment identity were appropriate for lower-income settings, the fact that fertility transitions accompany economic growth would make it unclear as to whether either model of savings would be appropriate to simulate the effects of demographic change.

In this study, we adopt the model proposed by Karra, Canning, and Wilde (2017) [20], hereafter referred to as the CKW Model, to quantify the magnitude of the effect of savings on the Demographic Dividend. We use four different approaches to model savings: 1) an approach where investment is equal to domestic savings, but where domestic savings is low, constant, and independent of demographic change; 2) an approach where investment is generated from domestic savings, which varies based on country demographics - here, the demographic impact on savings is maximized as all additional disposable income that is generated from demographic change is saved; 3) an open economy modeling approach, where investment is generated from international capital markets (foreign direct investments); and 4) a cross-country modeling approach that empirically estimates investment as a function of savings and shifting demographic structure. Of the four proposed approaches, the second approach to inferring the role of savings is most often used in the Demographic Dividend literature, while the first approach to estimating savings has been less widely used. In contrast, the last two approaches have been almost completely ignored. By comparing the results from each modeling approach, we can not only provide bounds of magnitudes for the savings effect but also can show the importance of the savings effect relative to the other channels through which the Demographic Dividend affects production. By estimating how the different assumptions affect the size of the Demographic Dividend, we can also ground the discussion on savings and the Demographic Dividend along more empirically justified lines.

We find that, for realistic parameter values from cross country evidence, the size of the Demographic Dividend under all four savings and investment modeling assumptions are essentially identical. This result implies that it may not be realistic to assume large savings effects from the Demographic Dividend and that caution may be warranted when using this channel as a motivating economic rationale for fertility decline.

II Four Theories of Savings and Investment

In this section, we describe the four main approaches to modeling how population changes may contribute to economic growth and output through changes in savings and investment, and we review the current evidence for each model.

II.A Theory 1: Low Constant Domestic Savings Rates

In studying the relationship between demographic change, savings, and growth, a natural starting point would be to consider the dynamics of savings behavior within a life-cycle framework, where changes in age structure can contribute to potentially large changes in savings [1, 14, 30]. However, evidence from low- and middle-income countries has shown that reduced population growth may have a negligible effect on saving and may even lead to lower aggregate saving rates [8, 27, 36]. Several studies of household savings in a number of developing countries have been inconclusive about the relationship between the number of children and savings [11, 33]. Moreover, even if children discourage saving, it is possible that the rate of growth effect may offset the dependency effect so that reduced population growth leads to lower rates of saving - this may be more likely to occur in economies that are experiencing slow or no growth [27].

A possible approach to incorporating a demographic effect on national savings or investment would be to combine data on age-specific saving rates[1] with the evolving age structure of the population across each scenario of demographic change. However, such data are generally not available for developing countries, and the data that do exist show little evidence of life-cycle saving behavior. For example, Deaton (1992) [9] calculates household consumption and income over the life cycle in Cote d'Ivoire and finds no clear relationship between age and saving, consumption, or even income, while Deaton and Paxson (2000) [10] find that the trends in the aggregate saving rates in Taiwan could not be explained by changes in the relative sizes of different age groups (each with different savings rates) over the life cycle.

In addition to there being limited empirical data on savings, particularly in low-income settings, there exist several conceptual concerns when using age-specific saving rates. For example, Weil (1994) [40] notes that data on age-specific saving does not take into account externality effects that are transmitted through generations and through which factors that include support of children and the elderly, bequests, and other transfers impact savings behavior. These intergenerational flows are likely to change as the age structure of the population, and particularly the dependency ratio, changes, which would impact age-specific savings rates.[2] In addition, the permanent income hypothesis would suggest that most of the additional income from a reduced dependency burden, which constitute a permanent income change, would likely be consumed - the increase in savings would be small, if not zero, in a life cycle savings model [1, 30].

With these considerations in mind, we parametrize savings rates to be low and constant under this modeling assumption.

[1] For example, Poterba (1994) [34] presents data on age-specific saving rates in a number of developed countries.

[2] If, for example, there were a sudden reduction in the number of children aged 0-4 in a population, then holding both the size of all other age groups and the age-specific saving rates constant would imply that the reduction in the number of children would not have any effect on the aggregate saving rate. However, we observe that such a reduction would likely reduce the dependency burden that working-age adults face, thereby resulting in higher consumption, savings, or both.

II.B Two Theories of How Demographic Change Affects Savings Rates

Conceptual discussions of the Demographic Dividend have often emphasized the benefits of demographic shifts in age structure, particularly the shift towards a relatively larger fraction of the working-age population, on national saving [5, 6, 24, 28]. In addition to directly raising income per capita by lowering the dependency ratio, the capital accumulation from this extra saving may result in an increase in the output per worker [2]; however, the empirical evidence for the population-induced translation of savings to investment and capital accumulation, particularly in low- and middle-income countries, is limited and weak [8, 36].

We examine two cross-country evidence-based approaches for the role of changing age structure on savings. Our first approach follows the model of Bloom et al. (2007) [4] in which we directly estimate savings as a function of changes in the dependency ratio using cross-country data and parametrize savings based on the estimated coefficients. Our second approach utilizes new data on national investment and savings from the Penn World Tables 9.1. We then use the National Transfer Accounts (NTA) data on life cycle savings and consumption [24] to conduct a bounding exercise and estimates rates of savings of new "available" income that would be needed in order to generate a sizable savings effect. We describe these two approaches in greater detail in the following sub-sections.

II.B.1 Theory 2: Deriving Savings Using Cross Country Estimation

In their 2007 study, Bloom and colleagues re-examine existing theories of life-cycle savings that rest on the premise that people at different ages save at different rates changes, and changes in aggregate savings would in turn be driven by changes in age structure. The authors innovate on these existing models by theorizing how changes in life expectancy might additionally impact savings behavior both directly as well as through changes in retirement decisions. To test their theory, the authors estimate a dynamic aggregate savings model using 40-year country-level panel data in which the savings rate is a function of lagged savings, income, the presence of a social security system, and the population age structure, proxied by the old-age and youth dependency ratios.

The approach by Bloom et al. (2007) [4] to estimating the evolution of savings as a function of demographic change was replicated in the CKW Model using data from the Penn World Tables. In this approach, we again refer to data on investment and trade balances as a fraction of GDP from the Penn World Tables, which we use to differentiate between domestic national savings and investments using the open economy savings-investment equivalence identity from macroeconomic theory.[3]. As was shown in Figure 1, national savings and investment are unrelated for the developed world, where financial markets are more advanced, thereby making it easier for capital to flow across borders; on the other hand, the correlation between savings and investment is stronger in low- and middle-income countries, with a correlation coefficient of 0.32. Using these data, we follow Bloom et al (2007) [4] and the CKW Model approaches by estimating parameters for investment rates for income and demographic characteristics in a cross-country fixed effects panel, which we then import into our model to predict savings rates as a function of income and demographic change.

II.B.2 Theory 3: National Transfer Accounts Evidence

A common feature of the two aforementioned theories of savings is that both approaches emphasize the role of age structure shifts on savings behavior through changes in age-specific savings rates. An alternative approach in the literature has been to examine how demographic change influences savings patterns through changes in age-specific income and consumption. As an example, Figure XX, which uses data from Soyibo, Olaniyan, and Lawanson (2009) [39], presents life-cycle patterns of consumption and labor income for Nigeria in 20XX. Here, the gap between consumption and labor income at any age is accounted for through transfers (either intergenerationally through family or through institutions) between age groups, through non-labor income (such as rent on land or capital), and through net changes in savings. The construction of data like these for a large num-

[3]In particular, the open-economy equivalence identity stipulates that the trade balance must equal capital flows and that investment equals national savings net of capital outflows, or $I = S - NX$ (equivalently $S - I = NX$)

ber of countries has been a central goal of the National Transfer Accounts project [24].

As Figure XX indicates, a change in the population age structure that would increase the fraction of the population in their mid-life working years, where labor income would exceed consumption, would expand society's budget constraint. As a result of this expansion in income, it will therefore be possible for either average consumption or for savings to rise, if not both; however, it is not immediately clear how each of these factors would rise or in what proportion.

One additional key consideration that must be factored in is the role of non-labor income on consumption and savings, which is not presented in Figure XX. To calculate the impact of non-labor income, we begin with data on the aggregate national saving rate in Nigeria in 2015 from Heston, Summers, and Aten (2011) [16], which was estimated to be 14.X percent. We then impute total non-labor income by calibrating consumption and labor income profiles, as well as the age structure of the population, to this saving rate. That is, defining x_{2015} as non-labor income per capita in 2005, and c_i and w_i as consumption per capita and labor income per capita, respectively, at age i,

$$0.14X = 1 - \frac{\sum_{i=0}^{100} N_{i,2015} c_i}{x_{2015} \sum_{i=0}^{100} N_{i,2015} + \sum_{i=0}^{100} N_{i,2015} w_i} \tag{1}$$

In the Nigerian data, the level of x_{2015} is 30,586 Niara per capita. This implies that non-labor income is 60 percent of total income, which is not inconsistent with our model in which production is Cobb-Douglas and labor's share of manufacturing income is 66 percent and capital's share is 33 percent.

We can now look more explicitly at how changes in demographic structure affect consumption possibilities. When the age structure of the population changes, labor income per capita shifts because people at different ages have different levels of labor income; however, the consumption "needs" of the population also change at different ages [29]. Although we do not model this explicitly, we assume that the varying patterns of consumption by age reflect both changing biological needs for consumption over the life cycle as well as the shifts in the relative proportions of consumption across different groups in society. For tractability, we assume that these relative levels of consumption, which we denote as "consumption needs", do not change as the age structure of the population changes. Slower population growth, through the reduction in the fraction of the youth population, would therefore redistribute population shares to include more people in ages that have higher relative consumption needs; this effect mitigates some of the benefit from having a larger proportion of the population earning labor income.

Combining the change in labor income with the change in consumption needs, we can calculate the demographically-induced increase in available demographically-adjusted income, net of demographically-adjusted consumption needs, relative to a base year of 2005, which we denote as the "change in disposable income ΔDI_t". This approach is derived from Lee (1980). That is,

$$\Delta DI_t = \left[x_t \sum_{i=0}^{100} N_{i,t} + \sum_{i=0}^{100} N_{i,t} w_i - \sum_{i=0}^{100} N_{i,t} c_i\right] - \left[x_{2015} \sum_{i=0}^{100} N_{i,2015} + \sum_{i=0}^{100} N_{i,2015} w_i - \sum_{i=0}^{100} N_{i,2015} c_i\right] \quad (2)$$

Finally, we consider how this extra demographically-induced disposable income will be divided between saving and consumption. In a naive model, one might assume that needs-adjusted consumption remains constant, while the additional disposable income is directly translated into savings - this would indeed yield a very large Demographic Dividend in terms of capital accumulation. However, we do not find evidence for such an assumption because it ignores one of the major reasons as to why people in their prime working years have lower consumption than earnings - they transfer resources to people in other age groups [23, 29]. When there are fewer dependents, there is less need for such transfers, and working-age adults can, in turn, afford to consume more disposable income. The shift in population age structure therefore relaxes the household budget constraint in a similar fashion to that which would result from having higher income. Thus, rather than assuming a fixed schedule of age-specific consumption in the face of demographic change, a more reasonable course may be to observe how demographic change may induce shifts in the marginal propensity to consume (MPC).

For such a commonly discussed parameter in macroeconomic theory, there are surprisingly very few available estimates of the MPC, particularly from low- and middle-income settings. Using time series data for the United States, Feldstein (2009) estimates the MPC from real disposable income to be 0.70 [13]. Similarly, a Federal Reserve Board model for the United States in the mid 1990s estimated the MPC from labor income to be 0.51 [7]. In a study of income variations caused by weather variability among farmers in Thailand, Paxson (1992) finds an MPC ranging between 0.17 and 0.27. Kan, Peng, and Wang (2011) look at the consumption response to a voucher program in Taiwan, and they calculate an MPC of 0.33 [19]. In reviewing these estimates, it should be noted that they each infer the MPC using short-run variations in income, which is important because the MPC to consume out of short-run income is typically lower than the propensity to consume out of longer-term changes in income [14, 15]. Given that the demographic changes that we are considering are relatively long-term in nature, a higher MPC is more likely to be an appropriate estimate. Indeed, if we are to evaluate population shifts in age structure that are generated over a decade or more, the right assumption might be that the MPC is closer to the average propensity to consume; that is, $APC = 1 - s$, where s is the savings rate. This is the assumption that is used previously, where the savings rate is constant.

Given that we have little reason to be confident of which value for the MPC would be more appropriate, we simply present our estimates for the full range of values, i.e. an MPC from zero to one. Figure XX shows the impact of the shifting age structure on the aggregate savings rate under different values for the MPC. Savings is shown in the low-fertility relative to the medium-fertility scenario. In the case where the MPC is zero, the saving rate is 21.1 percent higher in the alternative scenario than in the baseline scenario over a 30 year simulation period. Even an MPC of 0.5 leads to saving being 13.3 percent higher in the alternative scenario compared to the baseline scenario over a time horizon of 30 years. It is interesting to note that, unlike the analysis of Bloom and Williamson (1998) [6], the demographic window for high savings does not "close" after a few decades.

The reason is that fertility starts at such a high level that the faster decline in fertility in the alternative scenario results in only a very minor increase in old-age dependency relative to the baseline scenario.

II.C Theory 4: International Trade Flows

An important part of our results is driven by the assumptions of savings behavior under a Solovian model of savings. It is possible to relax this assumption in a straightforward way by assuming that the economy is open to international capital flows that equalize the return to capital around the world, or at least up to a country fixed effect. In a small open economy, domestic real interest rates will be fixed by the world interest rate. As such, one strategy to add international capital flows to the existing CKW model would be to determine the "world" interest rate that is to be set in the first period of the model and to fix that interest rate for all time periods in the model. Capital will therefore evolve in accordance to this interest rate. The benefits to such an approach are as follows:

1. It allows for a more realistic view of capital in the capital-intensive (e.g. manufacturing) sector in Sub-Saharan African economies, which are often highly dependent on foreign direct investment for their productive capital; in Sub-Saharan Africa, more than XX percent of overall productive capital is sourced through foreign direct investment (CITE to answer if this is true)

2. Calibration of the world interest rate and the allowance for international capital flows eliminates the need to parameterize the capital side of the economy, including the initial level of capital as well as capital accumulation. This approach also eliminates the need to parameterize both the savings function (since capital flows dynamically) as well as the world savings rate (since it will be determined endogenously by the model).

3. In the standard CKW model, we exploited the fixed capital-labor ratio (i.e. we set $\alpha = 2\beta$, where $\alpha = \frac{1}{3}$ and $\beta = \frac{1}{6}$) in order to find closed form solutions for labor market allocations across sectors, which we

derived by solving for the Z_t term and solving for a quadratic function (refer to the CKW Appendix for details). In introducing an open economy setup, we can obtain closed form solutions for each variable independently of the ratio of α and β, thereby eliminating the need for a fixed capital-labor ratio assumption (see theory section below).

In taking an open economy approach, however, we note that that demographic shifts will no longer affect capital accumulation directly since capital flows will not be dependent on changes in household savings rates as fertility falls. Instead, demographics will only interact with the model as the marginal product of labor changes; as the population in the alternative scenario declines in size relative to the baseline scenario, more capital will flow in due to a relatively higher marginal product of labor. This inflow of capital due to increases in the marginal product of labor would also be observed when the marginal product of labor rises due to improvements in education, health, etc.

III Methods

We begin by following Karra, Canning, and Wilde (2017) [20], who developed a macrosimulation model to assess the effect of fertility reduction on economic growth. This model is somewhat complex, as it incorporates over 10 individual channels through which fertility decline can affect economic growth. One of the channels, which is of key interest to this study, is capital deepening. The full details of the CKW model is provided in the appendices; a brief visual guide of their model structure is depicted in Figure 1.

IV Data and Parameter Calibrations

Our simulation is focused on interventions that alter the path of fertility from what would otherwise occur along a given baseline. We start with the current population age structure in the baseline scenario and assume that fertility and mortality will follow the United Nations' baseline high-variant forecast of fertility, which is projected over a 100-year time horizon. Our alternative scenario follows the United Nations' low-variant fertility projection, which assumes a one-birth decline in the fertility rate over the first 15 years of the time horizon and a sustained one-birth difference in fertility from the high-variant scenario over the remainder of the time horizon. We examine baseline and alternative scenarios constructed using demographic data from Nigeria. Our baseline (high-variant) and alternative (low-variant) scenarios are constructed using vital rates from Nigeria and the 2019 Revision of the United Nations' World Population Prospects. Baseline data on age-specific fertility rates and projected populations are also taken from the 2019 revision [32].

For our economic model, we collect baseline data for modern (capital-intensive) sector and traditional (labor-intensive) sector outputs from a variety of sources. These sources are described in Tables 1 and 2, and include data on health and education from the 2008 Nigeria Demographic and Health Surveys (DHS), macroeconomic indicators from the Penn World Tables [12] and the World Development Indicators [3]. We also gather information on labor force participation from the International Labor Organization [18]. Estimates of our model parameters are obtained from a wide range of well-identified, micro-founded studies, as is outlined in Table 1. We build upon Karra, Canning, and Wilde (2017) [20] by re-deriving the evolution of savings, as shown in Appendix A, to allow for world interest rates to dictate national investment rather than domestic savings, which allows us to assess the effect of international capital flows.

V Results

We present our main findings in a series of figures, which plot the evolution of each of our main variables of interest under the four different savings and investment scenarios described above, for a high "baseline" fertility scenario relative to a lower "alternative" fertility scenario. For ease of comparison, rather than presenting the absolute levels of each variable for both fertility paths under all four savings and investment models, we simply show one path per investment model as a percentage change from what would have been been under a baseline higher fertility scenario. This is similar to the methodology of presentation from Ashraf, Weil, and Wilde (2013) [2] and

Karra, Canning, and Wilde (2017) [20].

Figure 3 plots the path of income per capita predicted by our model, under the "endogenous low" CKW model fertility path, relative to the path of income predicted under the "baseline" high fertility scenario. Each of the four lines represents this relative comparison for each of the four savings and investment models: 1) Constant Savings, which assumes that demographic changes in age structure does not induce higher savings rates; 2) International Capital Flows, which assumes that capital formation occurs in an open economy and is independent of domestic savings; 3) Cross-Country Evidence, which assumes that changes in population age structure do affect savings and investment rates and are parametrized by our cross-country predictive regression model; and 4) Maximum Theoretical, which assumes that all of the additional household income that is generated by changes in age structure, as suggested by the National Transfer Accounts estimates, is translated to capital formation.

Figure 3 shows that the size of the Demographic Dividend in each of our four savings and investment scenarios are somewhat similar. In particular, the maximum difference between the four models by 2050 is only 6.2 percentage points. In fact, upon excluding the Maximum Theoretical model, the difference is only 1.4 percentage points. This gap is larger at the end of the time horizon of 2100, where the maximum difference is 38.4 percentage points. However, the largest gap across the three models, which rely on the assumption that domestic savings is important for investment, only differ by 13.4 percentage points, which translates to an annual growth rate of just 0.15%. This difference is observed between the Constant Savings model, where demographic change plays no role at all, and the Maximum Theoretical model, which assumes the maximum possible effect of shifts in age structure on the savings rate. Moreover, the difference between the Constant Savings scenario and the Cross Country Evidence model only yields a difference of 6.9 percentage points by 2100, translating to an annual growth rate of 0.08%. The only model which produces a significant difference in the size of the Demographic Dividend is the International Capital flows model; specifically, changes in age structure in this model yield larger dividends in the short run but a smaller dividend in the long run.

Figures 4 and 5 present the effect of the Demographic Dividend on capital formation, and on savings and investment rates.[4] As noted before, the effect of the Demographic Dividend is initially much higher in the international capital flows model relative to the three domestic savings models. However, investment rates are much lower in the long run, since under the population is much larger the high fertility scenario, which implies that more capital would flow in to equip the new larger labor force. One interesting characteristic of Figure 5 is that while savings rates are shown to be able to rise more significantly by demographic change (as shown in the Maximum Theoretical model), we find empirically that at the income level of countries in sub-Saharan Africa, savings rates remain at a very similar levels independently of whether or not fertility falls more slowly or more rapidly. This finding provides evidence for the constant savings theory of investment that is espoused by Deaton (1992) [8, 9].

VI Conclusion

In this study, we show that there is little empirical or theoretical support for large increases in domestic investment rates as part of the Demographic Dividend. Most arguments in favor of such increases assume that: 1) higher domestic savings rates will lead to higher levels of investment and capital accumulation; and 2) changes in age structure that are associated with fertility decline will increase investment rates. We demonstrate that both of these assumptions may be too optimistic in their reliance on the role of savings on investment and capital growth.

Using data from the Penn World Tables on capital flows and gross investment rates, we show that while there is a correlation between domestic national savings and investment rates, this correlation is not strong. This finding is consistent with an open economy model of capital flows, where domestic savings rates have little to no effect on gross investment rates. By extending the Karra, Canning, and Wilde (2017) [20] model to account for four very different investment and savings modeling assumptions, we show

[4] For the three domestic models, savings rates and investment rates are, by definition, equal. For the international capital flows model, we calculate what the savings rate would need to be in order to achieve the levels of capital accumulation that are derived from international capital flows.

there is little effect on the size of the Demographic Dividend. We show that the difference in annual economic growth is only 0.15% higher in a model that assumes the most favorable effects of demographic change on savings and investment compared to a model where there is no effect of population on savings behavior.

Using a predictive fixed effects regression model, we show that for many Sub-Saharan African countries, investment rates have, historically, stayed fairly constant until very late into the demographic transition. We argue that most of the literature establishing the effect of demographic change on investment was estimated using high-income data, so it is not surprising that we find a different pattern for low- and middle-income settings. Our finding is consistent with the conclusions of Deaton (1992) [8,9], who states that consumption rates in the developing world are high and fairly constant. As a result, the assumption that changing investment rates are a driver of the Demographic Dividend may be placing more weight on this mechanism than what the empirical evidence is able to bear. With this said, we find that caution is warranted when using increased savings as a rationale for promoting fertility decline.

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Figure 1: Visual Representation of the Karra-Canning-Wilde (2017) Model

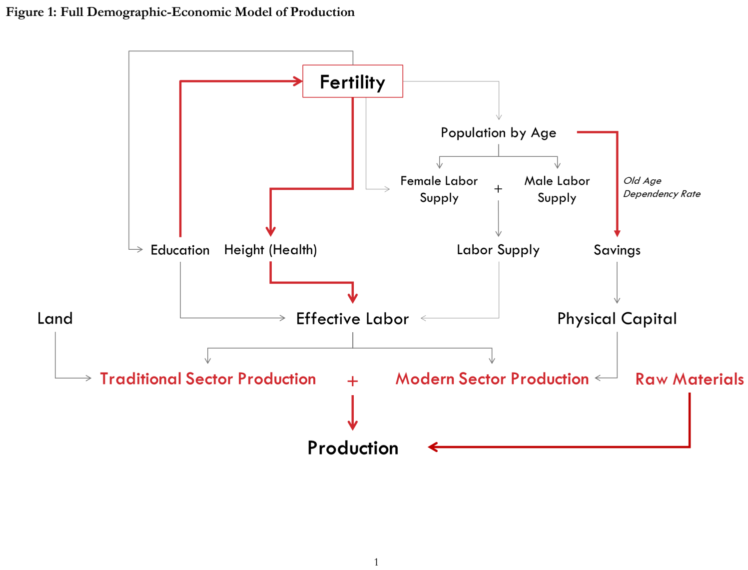


Figure 2: The Relationship Between Domestic Savings and Investment in Sub-Saharan Africa

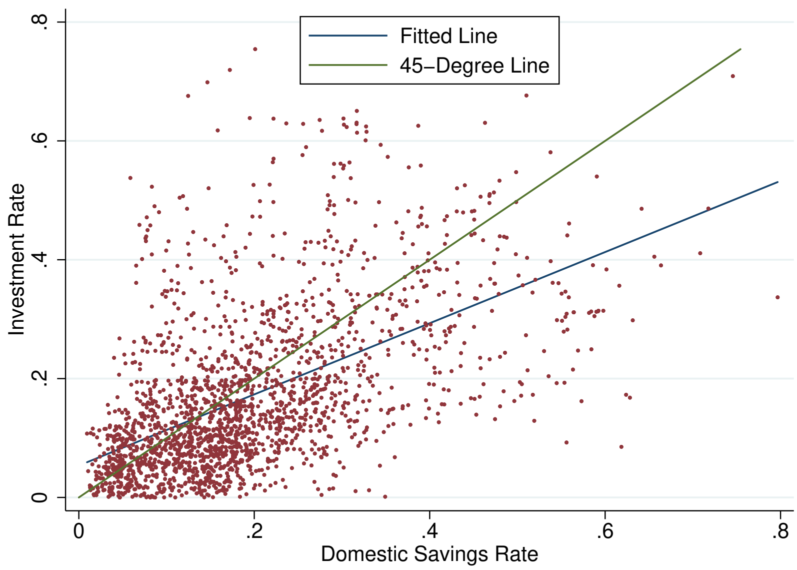


Table 1: Parameter Calibration

Parameter Symbol	Value	Description	Source(s)
π	0.02	Effect of fertility on female labor supply	Ashraf et al. (2013)
θ_E	0.2	Effect of fertility on childhood education	Joshi & Schultz (2007); Rosenzweig & Wolpin (1980)
ψ	-0.15	Effect of women's education on fertility	Osili & Long (2008)
θ_H	-0.00067	Effect of fertility on adult height	Giroux (2008); Joshi & Schultz (2013); Kravdal & Kodzi (2011); Stevens et al. (2012); Victora et al. (2008)
α	0.33	Capital share of output in modern sector	Hall & Jones (1999)
β	0.167	Land share of output in traditional sector	Kawagoe et al. (1985); Williamson (1998, 2002)
γ	0.1	Economic returns to schooling	Banerjee & Duflo (2005); Oyelere (2010); Psacharopoulos (1994); Psacharopoulos & Patrinos (2004)
λ	0.08	Effect of health on output	Schultz (2002, 2005)
δ	0.07	Depreciation rate of capital	Schmitt-Grohe & Uribe (2006)
ϕ_1	0.758	Effect of lagged savings on current savings	Bloom et al. (2007)
ϕ_2	0.133	Effect of wage rate on savings rate	Bloom et al. (2007)
ϕ_3	-0.006	Effect of squared wage rate on savings rate	Bloom et al. (2007)
ϕ_4	-0.209	Effect of ratio of old to working age population on savings rate	Bloom et al. (2007)

Table 2: Data Sources

Data Type	Source(s)
Baseline population by age and sex, 2010	UN World Population Prospects (United Nations, 2010)
Baseline age-specific fertility rates, 2010-2100	UN World Population Prospects (United Nations, 2010)
Years of education by 5 year age-sex groups, 2010	2008 Nigeria DHS (National Population Commission (NPC) [Nigeria] & ICF Macro, 2009)
Adult height by 5 year age-sex groups, 2010	2008 Nigeria DHS (National Population Commission (NPC) [Nigeria] & ICF Macro, 2009)
Labor force participation by 5 year age-sex groups, 2010	ILO (International Labour Office (ILO), 2013)
Output, 2005	Penn World Tables (Feenstra et al., 2015)
Output, 2010	Penn World Tables (Feenstra et al., 2015)
Oil Output, 2010	Penn World Tables (Feenstra et al., 2015)
Capital stock, 2010	Penn World Tables (Feenstra et al., 2015)
Agricultural land, 2010	WDI (World Bank, 2012)
Proportion of GDP between modern and traditional sectors, 2010	WDI (World Bank, 2012)
Proportion of labor between modern and traditional sectors, 2010	WDI (World Bank, 2012)

Figure 3: Income Per Capita

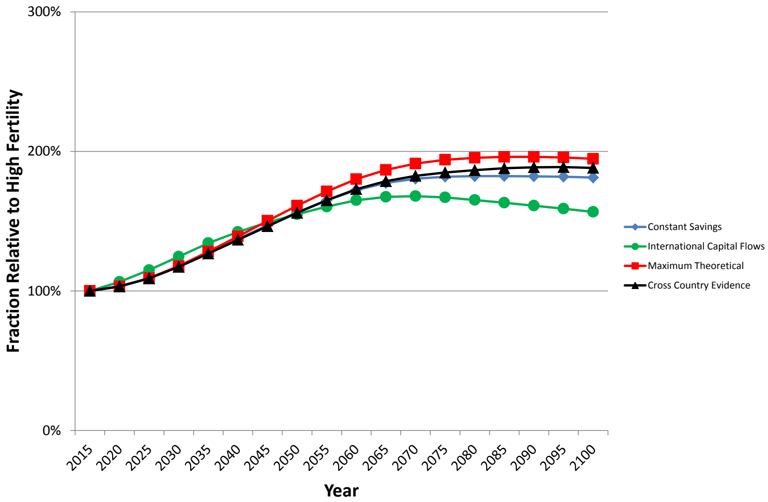


Figure 4: Capital per Worker

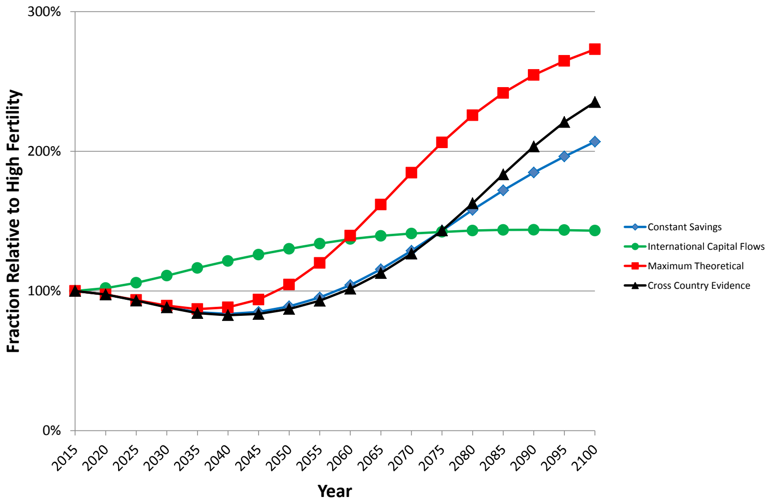
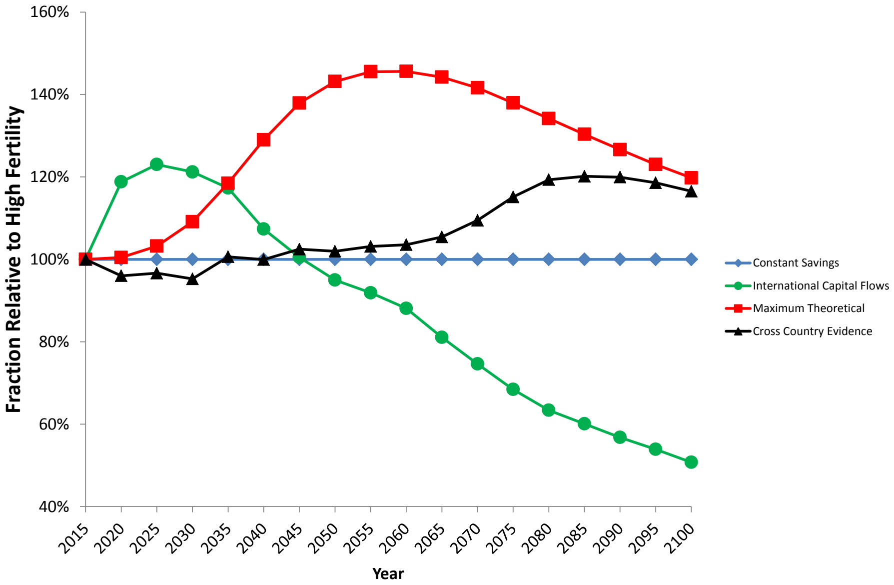


Figure 5: Savings



Appendix A: Open Economy Model Addition

Let r be the domestic interest rate. In a small open economy, $r = \bar{r}$, where $\bar{r}$ is the world interest rate which is fixed. To determine $\bar{r}$, note that in the initial period of the model, payments to capital will imply $\bar{r}K_0 = \alpha Y_M$, where K_0 is the initial level of capital, α is the capital share of income from the manufacturing production function, and $Y_{0,M}$ is manufacturing output in the initial period. Therefore

$$\bar{r} = \alpha \frac{Y_{0,M}}{K_0}$$

All of these are parameters of the model.

In subsequent periods, capital will evolve such that this world interest rate will remain constant in every time period. Therefore

$$K_t = \frac{\alpha}{\bar{r}} Y_{t,M}$$

Plugging in the production function for manufacturing income we get:

$$K_t = \frac{\alpha}{\bar{r}} AM_t LM_t^{1-\alpha} K_t^{\alpha} e^{\gamma E_t + \lambda H_t}$$

Solving for K_t we get:

$$K_t = \left(\frac{\alpha}{\bar{r}} AM_t e^{\gamma E_t + \lambda H_t} \right)^{\frac{1}{1-\alpha}} LM_t$$

In this case, K_t is now a function of LM_t, whereas before it was not. Therefore, we cannot use the original analysis in the paper with the quadratic. It is still true that:

$$Z_t LM_t^{-\alpha} = (L_t - LM_t)^{-\beta},$$

but now Z_t is a function of LM_t since Z_t is a function of K_t, which is now a function of LM_t.

We now resolve for Z_t by plugging in for the newly solved K_t. In the paper, Z_t above was (and still is in this case):

$$Z_t = \frac{(1-\alpha) \cdot AM_t K_t^{\alpha} e^{\gamma E_t + \lambda H_t}}{b \cdot AA_t X^{\beta}}$$

Plugging in for K_t yields:

$$Z_t = \frac{(1-\alpha)\cdot AM_t \left(\left(\frac{\alpha}{\bar{r}} AM_t e^{\gamma E_t + \lambda H_t}\right)^{\frac{1}{1-\alpha}} LM_t\right)^{\alpha} e^{\gamma E_t + \lambda H_t}}{b \cdot AA_t X^{\beta}}$$

$$Z_t = \frac{(1-\alpha)\cdot AM_t \left(\frac{\alpha}{\bar{r}} AM_t e^{\gamma E_t + \lambda H_t}\right)^{\frac{\alpha}{1-\alpha}} e^{\gamma E_t + \lambda H_t}}{b \cdot AA_t X^{\beta}} LM_t^{\alpha}$$

$$Z_t = \frac{(1-\alpha)\left(\frac{\alpha}{\bar{r}}\right)^{\frac{\alpha}{1-\alpha}} \left(AM_t e^{\gamma E_t + \lambda H_t}\right)^{\frac{1}{1-\alpha}}}{b \cdot AA_t X^{\beta}} LM_t^{\alpha}$$

Plugging this back into the Z_t equation above we have:

$$Z_t LM_t^{-\alpha} = (L_t - LM_t)^{-\beta},$$

$$\frac{(1-\alpha)\left(\frac{\alpha}{\bar{r}}\right)^{\frac{\alpha}{1-\alpha}} \left(AM_t e^{\gamma E_t + \lambda H_t}\right)^{\frac{1}{1-\alpha}}}{b \cdot AA_t X^{\beta}} LM_t^{\alpha} LM_t^{-\alpha} = (L_t - LM_t)^{-\beta}$$

$$LA_t = \left(\frac{(1-\alpha)\left(\frac{\alpha}{\bar{r}}\right)^{\frac{\alpha}{1-\alpha}} \left(AM_t e^{\gamma E_t + \lambda H_t}\right)^{\frac{1}{1-\alpha}}}{b \cdot AA_t X^{\beta}}\right)^{\frac{-1}{\beta}}$$

Since we have LA_t as a function of parameters and stock variables determined based on demographics from the previous period, LA_t can be found simply within our model without an appeal to a quadratic formula. And since L_t is given in every period based on demographics from the previous period, we can solve for LM_t directly as $LM_t = L_t - LA_t$. Once we have LM_t, we can plug that back into the equation for K_t above. With LA_t, LM_t, and K_t, we can find output, and iterate the model forward as normal.

Appendix B: National Transfer Accounts Evidence / Maximum Theoretical Model

Based on data from Soyibo, Olaniyan, and Lawanson (2009), we use the life-cycle patterns of consumption and labor income for Nigeria in 2004 to estimate the size of potential additions to savings after netting out transfers to or from other age groups. To calculate non-labor and national savings, we start with data on the aggregate national saving rate in Nigeria between 2010-2015, from Heston, Summers, and Aten (2011), which approximately 10 percent. We impute total non-labor income such that, given the consumption and labor income profiles, as well as the age structure of the population, we exactly match this saving rate. That is, defining x_{2015} as non-labor income per capita in 2005, and c_i and w_i as consumption per capita and labor income per capita, respectively, at age i,

$$0.14X = 1 - \frac{\sum_{i=0}^{100} N_{i,2015}c_i}{x_{2015}\sum_{i=0}^{100} N_{i,2015} + \sum_{i=0}^{100} N_{i,2015}w_i} \tag{3}$$

In the Nigerian data that we use as a benchmark, the level of x_{2015} is 30,586 Niara per capita. This implies that non-labor income is 60 percent of total income, which is not inconsistent with our model in which production is Cobb-Douglas and labor's share of manufacturing income is 66 percent and capital's share is 33 percent.

We can now look more explicitly at how changes in demographic structure affect consumption possibilities. When the age structure of the population changes, labor income per capita shifts, because people at different ages have different levels of labor income. In addition, however, the consumption "needs" of the population also change. Although we do not model this explicitly, we assume that the varying pattern of consumption by age reflects both changing biological needs for consumption over the course of the life cycle and the arrangements by which consumption is divided up among different groups in society.

For simplicity, we assume that these relative levels of consumption do not change as the age structure of the population changes, and we call them consumption needs, even though this is not very good terminology. Slower population growth, by reducing the fraction of the population made up of children, puts more people in ages that have higher relative consumption ñ this effect undoes some of the benefit of having more people earning labor income.

Putting together the change in labor income and the change in consumption needs, we can calculate the demographically-induced increase in available demographically-adjusted income less demographically-adjusted consumption needs relative to a base year of 2005. We call this term the change in disposable income ΔDI_t, which is again a slight abuse of terminology. This approach is derived from Lee (1980). That is,

$$\Delta DI_t = \left[x_t \sum_{i=0}^{100} N_{i,t} + \sum_{i=0}^{100} N_{i,t} w_i - \sum_{i=0}^{100} N_{i,t} c_i \right] - \left[x_{2015} \sum_{i=0}^{100} N_{i,2015} + \sum_{i=0}^{100} N_{i,2015} w_i - \sum_{i=0}^{100} N_{i,2015} c_i \right] \quad (4)$$

The final question is how this extra disposable income will be divided between saving and consumption. In a naive model, one might assume that needs-adjusted consumption remains constant while the additional disposable income all goes into savings. This would indeed give a very large Demographic Dividend in terms of capital accumulation, but we don't see it as being very sensible because it ignores one of the major reasons why people in their prime working years have consumption lower than earnings, which is that they are transferring resources to people in other age groups. When there are fewer such dependents, there is less need for such transfers, and so working-age adults can afford to consume more. The change in demographics slackens the household budget constraint in a fashion similar to the slackening that would result from higher income. Thus, in our view, rather than assuming fixed age-specific consumption in the face of demographic change, a more reasonable course is to invoke the idea of a marginal propensity to consume (MPC), a standard component of many macroeconomic models.

For such a commonly discussed parameter, there are very few available estimates of the MPC. Using time series data for the United States, Feldstein (2009) estimates the MPC out of real disposable income to be 0.70. In the Federal Reserve Board model for the United States in the mid 1990s, the MPC out of labor income was 0.51 (Brayton and Tinsley 1996). Paxson (1992) looks at income variations caused by weather variability among farmers in Thailand. She finds an MPC ranging between 0.17 and 0.27. Kan, Peng, and Wang (2011) look at the consumption response to a voucher program in Taiwan, and they calculate an MPC of 0.33. In considering these estimates, it should be noted that they are all concerned with the MPC out of short-run variation in income. The usual presumption is that the MPC to consume out of short-run income is lower than the propensity to consume out of longer-term changes in income. The demographic changes that we are considering are relatively long-term in nature, and so a higher MPC is presumably appropriate. Indeed, if we are considering a long run of a decade or more, the right assumption might be that the MPC is equal to the average propensity to consume, that is, one minus the saving rate. This is the assumption that is used in the previous part of the paper in which the saving rate is constant.

However, the purpose of this savings model is to assume the maximum possible theoretical change in the savings rate implied by demographic change as a bounding exercise. As such, we make the extreme assumption that that needs-adjusted consumption remains constant while the additional disposable income all goes into savings, or that the MPC for additional household income due to demographic change is 0.

Appendix C: Cross Country Evidence Details

In order to predict how the investment rates change as income and demography change, we expand upon the methodology of Karra, Canning, and Wilde (2017) who themselves follow Bloom, Canning, and Mansfield et al (2007), hereafter BCM. Specifically, to derive the savings relationship, BCM jointly solve the individual's lifetime labor supply, consumption, and savings using the lifetime utility maximization problem and derive an aggregate savings relationship. The parameters of this relationship are then estimated in a dynamic fixed effect panel model using data for a panel of countries 1960 to 2000. Karra, Canning and Wilde (2017) begin with this model, and after removing insignicant variables sequentially, they arrive at the follwing final regression specification which they use as their main savings equation:

$$s_t = \phi_0 + \phi_1 s_{t-1} + \phi_2 w_t + \phi_4 \frac{Old_t}{WA_t} \tag{5}$$

where w is the log of wages, s is the savings rate, and $\frac{Old}{WA}$ is the ratio of old to working age individuals.

In this paper, we expand on this model by noting that equation (3) is essentially a regression of savings rates on the lagged savings rate, a polynomial of income, and information on the fraction of the population in different age groups.[5] Since we only care about prediction of the investment rate and not causal inference, we expand the above regression to include as much information as possible on demographics, and include more non-linear effects in income. Specifically, we change equation (3) to predict investment rates instead of savings rates, and we now include up to a quintic term in our wage polynomial, substitute income for wages, and include a series of 20 covariates, one for the fraction of the population contained in each 5 year age group, minus a reference group (ages 50-55) plus a bin for those over 100 years. We also include country fixed effects and year fixed effects, and estimate this model on the Penn World Tables 9.1 data from 1950-2017.

Formally, we estimate the following predictive regression model:

[5] Wages and income are only different by a fixed fraction in our model since we use a constant returns to scale Cobb-Douglas production function, which constant will go into the intercept ϕ_0 when estimated.

$$i_{c,t} = \rho i_{c,t-1} + \sum_{i=1}^{5} \kappa_i y^i_{c,t} + \sum_{g \neq r}^{G} \sigma_g F_{g,c,t} + \eta_c + \omega_t + \mu_{c,t} \tag{6}$$

where i is the investment rate for country c in year t, $y_{c,t}$ is income, $F_{g,c,t}$ is a series of variables which measures the fraction of the total population which resides in each age bin g, where the reference bin

r is omitted. η_c and ω_t are country and year fixed effects respectively. Income is measured by dividing the variable *cgdpo* in the Penn World Tables by the population, while investment rates are given by the variable *csh_i*. The fraction of the population in each age bin is calculated from the UN Population Projections 2019 data.

To calculate the savings rate in our model, our calculated income, population structure, and lagged investment in one period are combined with our estimated ρ, κs and σs according to equation (4). The predicted investment rate is then used to iterate the model to the next period. Inital savings is parameterized in our model at 10 percent, which is similar to the average Nigerian investment rate from 2005 to 2015 according to the Penn World Tables. To calibrate the constant in equation (4), we solve for a steady state such that $s_t = s_{t-1} = s^*$ for the initial values of i, y, and the F_gs.