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 comes from increased savings by families with fewer children, leading to higher investment and increased formation of productive capital. However, conflicting evidence on the magnitude of the effect of reduced fertility on savings rates, in addition to a range of models on how those savings translate into investment, means the importance of this major theoretical channel is unclear. In this paper, we use a recent macrosimulation model from Canning, Karra, and Wilde (2017) to estimate the overall effect of savings under different, commonly used savings and investment assumptions. We find that changes in savings only contributes greatly to the demographic dividend under few and often unrealistic model assumptions, implying that caution is warranted when using increased savings as a 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 studied in the U.S. (Cutler, Poterba, Sheiner, Summers, & Akerlof, 1990), East Asia (Bloom & Williamson, 1998; Mason, 2001b), Egypt (Bloom & Canning, 2003), and in many other countries around the world (Kelley & Schmidt, 2001; Mason & Lee, 2004, NTA Project). Recent work by the Health Policy Plus Project, Ashraf, Weil, and Wilde (2013), Mason and Lee, and Karra, Canning, and Wilde (2017), 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 and 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 is widely believed to be a main driver of the demographic dividend. Given that savings rates at the household level vary with age, with a peak during people's working lives, aggregate savings at the national level will depend on the age structure of the population (Bloom, Canning, Mansfield et al. 2007; Higgins 1998; Lee, Mason, and Miller 2001; Leff 1969). 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 (Smith and Orcutt 1980; Weil 1994). Finally, higher savings rates from reductions in fertility rates may, in turn, boost the capital–labor ratio over and above the effect of having smaller inflows of working-age people.

While the theoretical role of savings has been discussed in the literature, many of the assumptions on the economic effect of demographically-induced changes in savings have not been tested empirically, and existing empirical evidence for the role of savings is limited. There is also a concern that the relatively prominent role of population-driven savings on growth may not be empirically supported, particularly in low- and middle-income settings. Many studies have typically assumed that all new "available" income will be saved, which 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 (Friedman, Modigliani et al). In addition, the literature on the role of savings on growth is couched in the savings-investment identity, which states that aggregate savings is equivalent to aggregate investment. However, domestic savings and investment are quite different (see Figure 2). In high-income settings, savings and investment are uncorrelated due to the open economy structure where international trade flows play a prominent role in savings and investment behavior. However, the equivalency of the savings-investment identity may be more suited for lower-income settings where international capital flows are more limited. Even if assuming a savings-investment identity was appropriate for lower-income settings, the fact that fertility transitions accompany economic growth would make it unclear as to whether either model would appropriately be fit to simulate the effects of demographic change.

In this study, we adopt the model proposed by Karra, Canning, and Wilde (2017) to quantify the magnitude of the effect of savings on the demographic dividend using three different approaches to modeling savings: 1) where investment is equal to domestic savings, but domestic savings is constant and independent of demographic change; 2) where investment is generated from domestic savings, which varies based on country demographics; and 3) where investment is generated from international capital markets, which is consistent with an open economy model. The second theory is generally used in the demographic dividend literature, while the first theory is much less used. The open economy aspect of capital flows has been almost completely ignored in this literature. By comparing and contrasting the results from each model, we can not only provide bounds of magnitudes for the savings effect, but also show the importance of the savings effect relative to the other channels through which the demographic dividend affects output. 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 three savings and investment assumptions are essentially identical. This result implies that it may not be realistic to assume large capital deepening effects from the demographic dividend, and that caution is warranted when using this channel as a rationale for promoting fertility decline.

II Methods

We begin by following Karra, Canning, and Wilde (2017), 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 which is capital deepening and is the primary subject of this article. The full details of the CKW model is available in the original article, and will be provided in the appendices in future versions of this paper; a brief visual guide of their model structure is depicted in Figure 1.

III 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 population age structure, fertility, and mortality rates in the baseline scenario, which predict a baseline demographic path. Our economic model then predicts income based on demographic change along that baseline path. Then we re-run the model for an alternative and lower fertility path, and compare the baseline and the alternative as the effect of fertility decline on income, or the demographic dividend.

Our baseline demographic scenario is the UN's high-variant forecast of fertility for Nigeria. We contrast this with the UN low variant fertility scenario for Nigeria, which we use as our alternative path. These high- and low-fertility scenarios are constructed using the 2019 Revision of the UN's World Population Prospects. Baseline data on age-specific fertility rates and projected populations are also taken from the 2019 Revision (United Nations 2019).

For our economic model, we collect baseline data for modern-sector and traditional-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 DHS and macroeconomic indicators from the Penn World Tables (Feenstra et al., 2015) and the World Development Indicators (World Bank, 2015). We also use information on labor force participation from the International Labor Office (ILO, 2013). Estimates of our model parameters are gathered from a wide range of well-identified micro studies, as outlined in Table 1. We build upon Karra, Canning, and Wilde by re-deriving the savings equation as given 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.

IV Results

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

Figure 3 plots the path of income per capita predicted by our model, under the "endogenous low" fertility path, relative to the path of income predicted under the UN high fertility scenario. Each of the four lines represents this relative comparison for each of the four savings and investment models: Constant Savings, which assumes demographic shift does not induce higher savings rates; International Capital Flows, which assumes capital formation occurs in an open economy and is independent of domestic savings (see Appendix A for a mathematical derivation of how this affects our model); Cross-Country Evidence, which assumes that demographic shift does affect savings and investment rates, and is parametrized by our cross-country predictive regression model (see Appendix C for details on this model); and Maximum Theoretical, which assumes that 100% of the additional household income made possible by demographic shift suggested by the NTA goes to capital formation (see Appendix B for additional details).

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 time horizon of 2100, where the maximum difference is 38.4 percentage points. However, the largest gap in the three models which rely on the assumption that domestic savings matters for investment at all only differ by 13.4 percentage points, which is equivalent to an annual growth rate of just 0.15%. This difference is between the Constant Savings model, where demographic shift plays no role at all, and the Maximum Theoretical model, which assumes the maximum possible effect of demographic shift 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, or 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, demographic change leads to a larger dividend in the short run, but a smaller dividend in the long run.

Figures 4 and 5 shows the effect of the demographic dividend on capital formation, and on savings/investment rates.[1] 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 high fertility scenario the population grows much larger, and therefore more capital flows in to equip the new larger labor force if the demographic transition did *not* occur. One interesting characteristic of Figure 5 is that while savings rates are shown to be able to rise significantly more 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 stay at a very similar levels independent of whether fertility falls slowly or more rapidly. This provides evidence for the constant savings theory of investment espoused by Deaton (1992).

[1]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 derived from the international capital flows.

V Conclusion

In this paper, we showed 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 demographic structure 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 domestic savings on investment and capital growth.

First, using data from the Penn World Tables on capital flows and gross investment rates, we show in Figure 2 that while there is a correlation between domestic national savings and investment rates, this correlation is not that 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.

Second, by extending the Karra, Canning, and Wilde (2017) model to account for four very different investment and savings assumptions, we show the demographically induced changes in aggregate savings should have little effect on the size of the demographic dividend in the developing world. We show that the difference between a model with the most generous assumptions regarding the effect of demographic change on savings and investment – and a model with no effect whatsoever – annual economic growth is only 0.15% higher in the former.

Third, using a predictive fixed effects regression model, we show that for countries similar to sub-Saharan Africa, 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 developed country data, and so it is not surprising that we find a different pattern in the developing world. In addition, this finding is consistent with Deaton (1992), who finds 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 driver than what the empirical evidence is able to bear. Therefore, we conclude 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

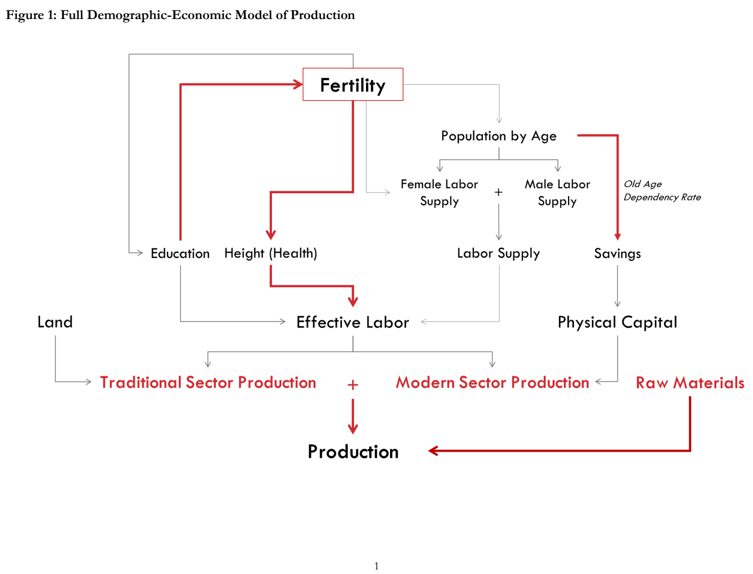


Figure 2: The Relationship Between Domestic Savings and Investment in Sub-Saharan Africa

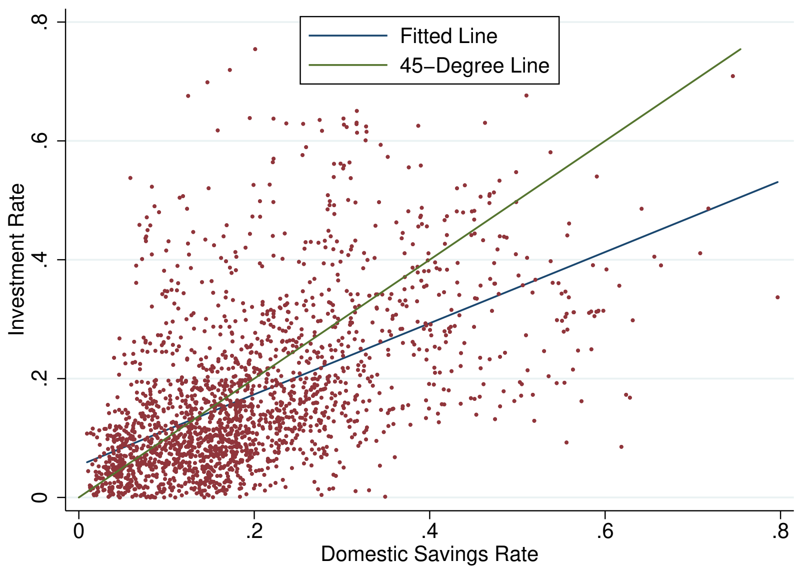


Table 1: Parameter Calibration

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

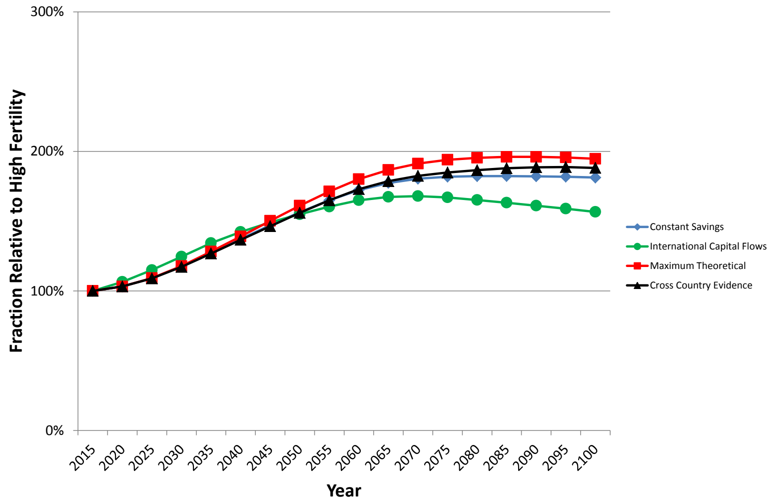


Figure 4: Capital per Worker

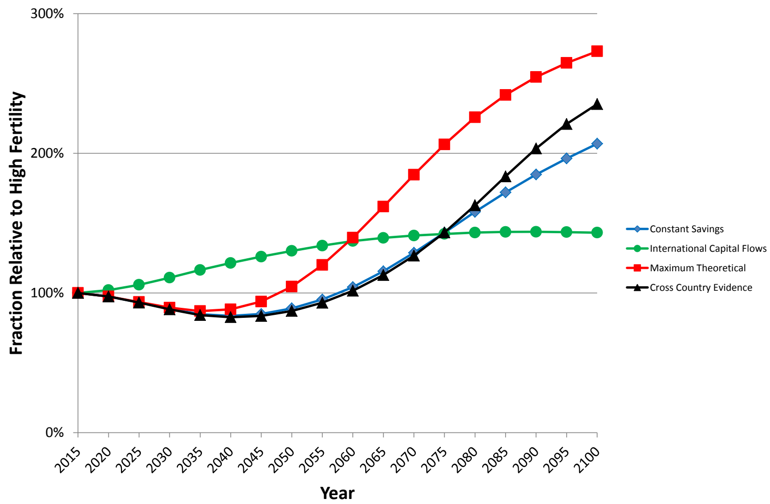
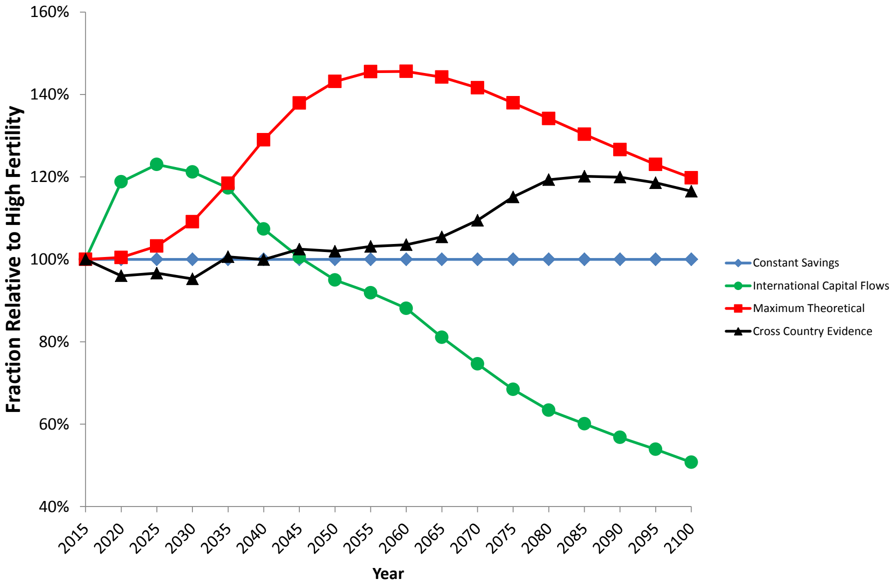


Figure 5: Savings



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_tvery simple 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

An alternative to looking at age-specific saving rates is to look at age-specific income and consumption. 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 (2017), which is 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 2015, and c_i and w_i as consumption per capita and labor income per capita, respectively, at age i,

$$0.10X = 1 - \frac{\sum_{i=0}^{100} N_{i,2015} c_i}{x_{2015} \sum_{i=0}^{100} N_{i,2015} + \sum_{i=0}^{100} N_{i,2015} w_i} \tag{1}$$

In the Nigerian data 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 2015. 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,

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

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 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:

$$s_t = \phi_0 + \phi_1 s_{t-1} + \phi_2 w_t + \phi_4 \frac{Old_t}{WA_t} \tag{3}$$

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.[2] 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:

$$i_{c,t} = \rho i_{c,t-1} + \sum_{i=1}^{5} \kappa_i y_{c,t}^{i} + \sum_{g \neq r}^{G} \sigma_g F_{g,c,t} + \eta_c + \omega_t + \mu_{c,t} \tag{4}$$

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

[2]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.

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.