The AIDS Epidemic, Family Structure and Economic Development: The Role of Reproductive Health and Family Planning Policies

Raül Santaeulàlia-Llopis
Department of Economics
Washington University in St. Louis

EXTENDED ABSTRACT (Work – very much – in Progress)

1 Introduction

Motivation: The Allocation of Global Funds to Fight AIDS. The largest donor to fight the AIDS epidemic is the United States that provided about 42% of all global funds committed for HIV/AIDS in 2005. U.S. aid primarily involves donor government assistance through bilateral aid (US$1,4 billion, that is, 49.6% of the global bilateral aid) and contributions to the multilateral organizations such as the Global Fund (US$275.3 million, 32.2% of the global contributions). [1] Members of the G7 and the European Commission have launched significant HIV/AIDS related initiatives and, consequently, total resources made available from all of these funding streams have increased from approximately $300 million in 1996 to $6.1 billion in 2004. [2] Most notably, because of its size, is the U.S. President's Emergency Plan for AIDS Relief (PEPFAR), [3] announced by President Bush in 2003, an umbrella organization for all existing US AIDS programs. PEPFAR is a 5-year, $15 billion, global initiative to combat AIDS and it represents a growing share of overall U.S. foreign assistance. However, perhaps, the most important feature of PEPFAR is its use allocation of funds. U.S. legislation authorizing PEPFAR specifies that only 20% of these funds be allocated to prevention of *HIV-infection* while about 70% go to cure and treatment (including palliative care) of *AIDS-progression*. [4] In more detail, the U.S. Congress required PEPFAR funds to be:

1. 55% for the treatment of individuals with HIV/AIDS – of which 75% between financial years 2006-2008 must be spent on the purchase and distribution of antiretrovirals (ARTs).
2. 15% for the palliative care of individuals with HIV/AIDS.
3. 10% for helping orphans and vulnerable children.
4. 20% for HIV/AIDS prevention – of which 33% must be directed at abstinence until marriage programmes.

[1] See `http://www.theglobalfund.org`.

[2] The G7 – Canada, France, Germany, Italy, Japan, the United Kingdom and the United States – and the European Commission accounted for 87% of all funds committed for HIV/AIDS in 2005. The World Bank and numerous entities in the United Nations also fund HIV/AIDS policies. The financial gap between what is provided and what is needed is a question I tackle later.

[3] See `http://www.pepfar.gov`.

[4] From the private sector, the Bill and Melinda Gates Foundation – the largest philanthropic funder in the HIV/AIDS arena – follows similar guidelines. In particular, most of the HIV/AIDS related funding provided by this Foundation is channelled as an active member of the Global HIV Vaccine Enterprise, an alliance of funders and research groups formed to accelerate HIV vaccine research.

This allocation of funds leaves very little role for Reproductive Health and Family Planning (RH/FP) prevention policies focused on *HIV-infection* reductions, and places the core strategy of AIDS-related policies on the treatment of *AIDS-progression* – mostly via the distribution of ARTs. Here, it is important to notice that ARTs treatment mainly targets one margin in which AIDS affects populations, that is, reductions in life expectancy through *AIDS-progression* rates. [5] However, it is well-understood that the AIDS epidemics reshapes populations in more margins – other than reducing life spans – in which RH/FP prevention of *HIV-infection* rather than ARTs treatment of *AIDS-progression* can play a major role. Firstly, AIDS kills selectively young adults – the most productive and reproductive individuals of a society – which changes the age distribution of the population and thins the ranks of working-age groups (the share of children and old adults per worker raises by as much as 20-25% in highly infected countries, see Jamison, Feachem, Makgoba, Bos, Baingana, Hofman, and Rogo (2006) and Stanecki (2004)). Here, notice that 85% of the *HIV infections* in Sub-Saharan Africa (SSA) are due to heterosexual intercourse, a margin where RH/FP polices can naturally assist. Secondly, AIDS, by increasing mortality and reducing fertility, also reduces population growth (by as much as .08% per percentage point of HIV prevalence, see Zaba and Gregson (1998)). In this context, Santaeulàlia-Llopis (2007) consistently integrates these three channels in which AIDS affects populations – life expectancy, demographic structure and population growth – and finds unambiguous large adverse effects of AIDS on economic development that can reduce the income per capita by as much as 12% at the peak of the epidemics and delay the process of industrialization of SSA countries by more than half a century. Importantly, he finds most of these aggregate effects on development are accounted for the AIDS effects on the demographic structure rather than on life expectancy. [6] [7] This opens room for integrated RH/FP and AIDS policies that target reductions in *HIV-infection* rates of young adults to have a large impact on economic development.

In addition, the AIDS epidemic represents an unprecedent seismic demographic shift to the structure of families in African societies that is raising the number of poor (widows and singles) households. Because AIDS kills mostly young adults, it also kills spouses and parents generating large numbers of widows and orphans (between one fifth and one fourth of all children in highly infected SSA countries are AIDS orphans, see UNAIDS (2006)). Moreover, the AIDS epidemic is associated with higher divorce rates and delays in first marriages pushing further the strain of single households, see Smith and Watkins (2005) and Reniers (2008). [8] This poses yet unexplored additional HIV/AIDS margins in which RH/FP policies naturally operate.

[5] AIDS reduces life expectancy by more than one third of a SSA lifetime (15-20 years) in HIV mature countries.

[6] The population growth – fertility – margin has invariably been the focus of attention in previous literature that has studied the effects of AIDS on development. Young (2005) finds in the context of a Solow model with some Beckerian elements that reductions in fertility due to AIDS generate a positive effect on the consumption per capita of future generations that offsets plausible losses in human capital of AIDS orphans. Kalemli-Ozcan (2006) uses the same margins than Young (2005) but argues the effect of AIDS on fertility is positive rather than negative, which, in the same context, leads her to attain negative results of AIDS on development. The work of Santaeulàlia-Llopis (2007), who builds a population model that integrates the effects of AIDS on life expectancy, demographic structure and population growth into a model of economic development – building a structural relationship between the demographic transition by age-specific groups and the development path (a structural shift of agriculture to industry and income per capita take-offs) – suggests a minor role for the fertility margin, and attributes most of the adverse effects of AIDS to changes in demographic structure.

[7] In other contexts, the importance of the demographic structure for economic development has also been emphasized for example by Williamson (1998) and Bloom, Canning, and Sevilla (2002).

[8] Also, the impact that AIDS has on individuals is also very uneven, for example, at early ages of adulthood AIDS affects mostly women while at later stages of the life-cycle AIDS affects mostly men.

In all, the discussion above seems to suggest there are potentially strong economic arguments that point to an immediate increasing reallocation of new funds that increase the number of integrated RH/FP and AIDS policies targeting prevention of *HIV-infection*. With this regard, the range of integrated RH/FP and AIDS policies is wide: reduce *HIV-infection* of adults by counselling on the use of condoms (see Bracher, Santow, and Watkins (2004)), circumcisions, treatment of genital soars (see Oster (2007)) or abstention; increase prevention of mother-to-child *HIV-infection* at pregnancy, delivery and breastfeeding; and, identify, support and counsel the planning of families that foster or care for AIDS orphans. However, we do not know the aggregate economic effects of each of the AIDS related polices yet, neither those RH/FP policies that focus on prevention to reduce *HIV-infection* nor those that currently focus on ARTs treatment to reduce *AIDS-progression*. This is the task of my research, evaluate such policies in terms of economic development.

A Successful Story on Prevention: Uganda. Uganda is a success story with regard to prevention of *HIV-infection*. There has been a general decline in the HIV prevalence rate among antenatal mothers at urban (rural) sites throughout the country from about 30% (14%) in 1992 to 10% (5%) in 2002, see Okware, Kinsman, Onyango, Opio, and Kaggwa (2005). [9] The range of prevention policies have focuses on three main pillars: abstinence, being faithful and condom use. These were set under the knowledge that sexual transmission is by far the major mode of spread of HIV in Uganda. Collectively, these three pillars have become known as the ABC strategy and this approach has been adopted and implemented jointly by many partners. [10] The ABC strategy has been credited with most of the success in Uganda's reduction in HIV prevalence: the median age of sexual debut raised from 14 to 17 years between 1989 and 2002 (abstinence); there has been decline of over 60% of casual sex among 15-49 years between 1989 and 2002 while fertility rates are still as high as in late 1980s (being faithful); and the proportion of men (women) that ever used a condom rose from 15% to 55% (6% to 39%) between 1989 and 1995 [11]. These successful policies follow RH/FP guidelines to prevent new *HIV-infections*.

Question. How much would the development path – in terms of income per capita and years to transit from agriculture to industry – of Malawi (a highly HIV-infected SSA country, 10.5% of its population is infected with HIV) change if we were to succeed in implementing integrated RH/FP and AIDS polices that reduce, similarly to Uganda, *HIV-infection* of young adults. Or, how much would the development path of Malawi change if we were to successfully implement integrated RH/FP and AIDS policies that reduce mother-to-child *HIV-infection* to zero?. Alternatively, how much would the development path of Malawi change if we were to deliver free treatment on ARTs that successfully reduce *AIDS-progression* to zero?. Do each of these policies increase income per capita and accelerate the industrialization process? If yes, by how much?.

I expect to provide quantitative answers to these questions such as: every US$1 million spent on RH/FP prevention policies that reduce *HIV-infection* of young adults by $x\%$ increases/decreases income per capita by $y\%$ and accelerates/slows down the industrialization process by t years; every

[9] Furthermore, the prevalence of HIV among patients attending STI clinics has decreased from 45% in 1990 to about 19% in 2002.

[10] At the same time, there has been a significant increase in the use of ARTs – and around 35,000 Ugandans were benefiting from ARTs in 2005. Noteworthy is that this development of ARTs has been suggested to generate complacency, or 'behavioral disinhibition', such as that which has been documented in some gay communities in the U.S. and Europe, see Katz, Schwarcz, and Kellog (2002) and Baily, Bastos, and Desai (2005). This may require scaling up prevention policies.

[11] Also, regular condom use with non-cohabiting partners rose from 5% in 1987 to over 60% in 2002

US$1 million spent on RH/FP prevention policies that reduce mother-to-child *HIV-infection* by $x\%$ increases/decreases income per capita by $y\%$ and accelerates/slows down the industrialization process by t years; and, every US$1 million spent on ARTs treatment that reduces *AIDS-progression* by $x\%$ increases/decreases income per capita by $y\%$ and accelerates/slows down the industrialization process by t years. In doing so, I will have extreme details on the the degree of heterogeneity in which AIDS operates since I am going to index individuals by a wide set of characteristics and keep track of them and their families over time – as I briefly expose in some detail in the next section. This allows me to be very specific in our targets, that is, we can learn the economic outcome of targeting not only different economic or demographic groups but also at different points in time or different stages of the AIDS epidemic. [12]

How do I plan to answer the question?. If we want to evaluate how much AIDS-related policies – both, those RH/FP policies focused on preventing *HIV-infection* and those treatment policies focused on reducing *AIDS-progression* through ARTs – increase (or not) the consumption per capita of SSA countries or accelerate (or not) the process of industrialization, we need to build a framework with a rich population process that captures the set of individuals and families in a society that is relevant to incorporate the margins through which AIDS distorts the structure and evolution of families. To do so, I build a population model on the basis of a large but finite number of individuals and family types that can be used to: $i)$ $identify$ the effects that AIDS has on individuals and their family's composition over time isolating those due to *HIV-infections* from those due to *AIDS-progression*, and $ii)$ $consistently\ aggregate$ the demographics of a society (with AIDS and no-AIDS scenarios) in a tractable manner that we can incorporate into a development theory to provide aggregate economic outcomes - income per capita and agricultural share of output. The fact that we can separately identify the effects of *HIV-infections* from *AIDS-progression* on individuals (hence, families) allows us to answer the ultimate policy questions we are interested in.

2 The Model

To capture all relevant types of individuals, families and its dynamics, I define a family as a vector z_t that subsumes the age, sex, marital status and health status of each of its individuals in period t. Next, I carefully define this vector and, most importantly, its evolution over time.

Demographics. Formally, every period t individuals are indexed by age $i \in \{1, 2, 3\}$ that represents childhood, adulthood and old age – a technical device called $exponential\ aging$ allows to consider time in shorter intervals than age groups. [13] [14] Adults differ in sex $g \in G = \{f, m\}$, respectively female and male, and I denote their individual state by z^{ig}. The individual state

[12] For example, one can think of a plausible non-monotonic relationship between individual HIV status and socioeconomic status: at early phases of the AIDS epidemic more educated (or rich) individuals are more likely to get infected with HIV in SSA countries because those individuals, we think, have higher contact exposure (some weighted, by risk, product of the number of sexual partners and the frequency of sexual intercourse) since they can afford them – and we know that more than 80% of the HIV infections in SSA are due to heterosexual intercourse. Later on, as the AIDS epidemics evolves, more educated individuals are, for whatever reason, the ones that change faster their behavior towards HIV – perhaps due to resources (access to information or prevention technology) or preferences (less reluctant to use condoms or secure the number of partners)

[13] The age grouping responds to balance the tractability and accuracy of the economic model.

[14] The data counterpart of childhood is individuals below 15 years old, young adulthood includes individuals between 15 and 49 years old, and old age represents individuals 49 years old and above.

of young adults may take different values depending on his/her health status, $z^{2g} \in \{0,1,2,3\}$, respectively deceased, AIDS-progressed, HIV-infected (HIV+), or healthy. [15] I assume HIV-infected young adults die before they reach old age and old adults can not be infected with HIV, hence, old adults must be either dead or alive and healthy, in that order, $z^{3g} \in \{0,3\}$. In addition, the marital status of adults can be single or married. For $i \in \{2,3\}$, households with $z^{if} \neq 0$ and $z^{im} \neq 0$ include a married adult couple of age class i; households with $z^{if} \neq 0$ and $z^{im} = 0$ include a single female adult of age class i; and households with $z^{if} = 0$ and $z^{im} \neq 0$ include a single male adult of age class i. Further, let $z^1 \in [0,N]$ be the number of (asexed) children born by adults in the household, where N is the maximum amount of children a household can host. I consider all children within households are identical and condition their mortality and birth rates on the age-class, marital and health status of the biological mother and on the stock of children in the household. [16]

A household consists of a set of people of up to three different generations with at most an elderly couple, and adult couple and maximum number N of children. Any proper subset is also a household type. Precisely, a household is a vector that states the relevant properties to each member's current demographic fate,

$$z = \left(z^1, z^{2f}, z^{2m}, z^{3f}, z^{3m}\right) \in Z = [0,N] \times \{0,1,2,3\}^2 \times \{0,3\}^2 \tag{1}$$

Note the information on the health status of each member is incorporated in the household type. This way, if I abstract from the HIV/AIDS status of young adult members, for a given number of children N, there are $2^4\ (N+1) = 16\ (N+1)$ possible types of households. If I consider the HIV/AIDS status of the young adults, there are $4^2 2^2\ (N+1) = 64\ (N+1)$ possible household types.

To specify the population process I construct a population matrix projection model with a Markovian structure. This formulation permits a discrete analysis that relates the entire population of each period to the preceding as follows

$$\mu^{t+1} = \Gamma\ \mu^t \tag{2}$$

where μ^t is the $64(N+1)$-dimensional population vector of family measures μ^t_z and the $64(N+1)$-by-$64(N+1)$ transition matrix Γ is the law of motion of the population. The typical element of the population projection matrix, $\Gamma_{z'|z}$, is the mass of families of type z in period t that transit to type z' in period $t+1$. Hence, the measure of families of a particular type z' at period $t+1$ is given by

$$\mu^{t+1}_{z'} = \sum_z \Gamma_{z'|z}\ \mu^t_z$$

Given an initial population vector μ^0 and Γ, iterative multiplications solve the matrix population model (2) and generate the population path for each family type z via numerical projections.

[15] The average time from infection with HIV to developing AIDS is about eight years, and from AIDS to death about one year if no anti-retroviral therapy is available. For children the incubation period is much shorter because their immune systems are not yet fully developed and most children infected at birth develop AIDS and die within 5 years.

[16] An ideal alternative is to explicitly consider the individual health status of each child, but this rises the state space by 3^N dimensions which is computationally very expensive. Another alternative, would be to HIV-infect an increasing proportion of children as a function of time (starting the date the mother is infected) that we could estimate from the data, or short-cut by HIV-infecting a constant proportion (the limiting one) the date the mother is infected.

Moreover, standard mathematical tools provide some useful results related to the asymptotic behavior and transient dynamics of the population. The Perron-Frobenius theorem states that if the nonnegative matrix Γ has the property of primitivity, then there exists a real positive eigenvalue λ_1 that is dominant (strictly greater than any other eigenvalue). [17] With regard to the long-term dynamics, the strong ergodic theorem establishes the limiting population grows at a rate equal to the dominant eigenvalue, λ_1, and converges to a stable population structure equal to the associated right eigenvector of λ_1, see Preston, Heuveline, and Guillot (2000) and Keyfitz and Caswell (2005). Stability is a property by which a time can be found when the several household types increase at rates that are arbitrarily close to one another. In that sense, we can think of this eigenvector as the balanced growth path of the demographic structure. With regard to the transient dynamics, the second eigenvalue governs the asymptotic rate of convergence.

The population path derived from current AIDS and non-AIDS environmental conditions is a key ingredient of my analysis. This population path represents the projected evolution of the demographic structure – a consistent aggregation of measures of individuals and family types – over time. For instance, consider a family that consists of n children, a married young couple with a healthy young female adult, a young male adult who has progressed to AIDS, and an old female adult in period t. This household is summarized by $z_t = (n, 3, 1, 3, 0)$. If we abstract from aging, the unfortunate events of the young female adult getting HIV and the death of the young male adult and one child represent the transition from $z_t = (n, 3, 1, 3, 0)$ to $z_{t+1} = (n-1, 2, 0, 3, 0)$. Consider another example where a household that consists of a healthy single female without dependents marries a healthy young male and bears a child next period. Abstracting from aging, such household transits from $z_t = (0, 3, 0, 0, 0)$ to $z_{t+1} = (1, 3, 3, 0, 0)$. These individual and family transitions obey HIV-infection rates, AIDS progression rates, mortality rates, fertility rates and divorce/marriage rates that are all conditioned on individual characteristics including age, sex, marital status, own HIV/AIDS status and HIV/AIDS status of their respective spouses. [18]

Technology. The production side of the economy has to take care of the stage of development and thereby the sectoral composition of output, in particular, of the fact that developing economies have an agricultural sector that amounts for the major part of production and employment. To do so we will start with the neoclassical framework for developing economies introduced in Hansen and Prescott (2002) and Parente and Prescott (2005). We will also accommodate for home production as in Gollin, Parente, and Rogerson (2004), which allows us to explore the plausible importance of the reallocation of the market and non-market labor within households due to AIDS. Galor and Weil (2000) treat the stock of human capital as essential for development and our discussion also laid out plausible important effects of AIDS on human capital accumulation. To evaluate these

[17] By definition a population measure is a nonnegative object and human population projection matrices are nonnegative. Nonnegative matrices can be either reducible or irreducible. Irreducible matrices are those in which all stages can contribute, by any developmental path, to some other stage or stages (i.e., the monotone mixing condition). A typical example of a reducible matrix is that with postreproductive ages and for this reason I will allow old female adults to bear children with probability measure greater than zero (that if old females happen to be the youngest females in the household). In all, irreducibility is a necessary but not sufficient condition for stability because it does not rule out the possibility of endless cycles. Primitivity is the subset of irreducible matrices without endless cycles. Formally, a primitive matrix is an irreducible matrix that becomes positive (all its elements are greater than zero) when raised to sufficiently high powers. For irreducible stage-classified models, a sufficient condition for primitivity is the presence of at least one positive diagonal element.

[18] In addition, the passage of time will be represented by a natural aging process that makes all members of the family advance age levels – children become young adults, young adults age to old adulthood, and old adults die – and allows time periods (years) to be interpreted as being of shorter duration than the age intervals associated with a three age model (0-14,15-49,+49).

effects we could extend our neoclassical formulation with an educational sector as in the Lucas (1988) two-sector growth model implemented in Manuelli and Seshadri (2005).

Households Problem. I cast the households problem as a sequence of recursive problems because I will define the development path as non-stationary notion of competitive equilibrium that consists of a set of sequences of firms allocations, household policy functions, prices and wealth distributions that determine a transition from a stationary Malthusian-agricultural equilibrium to a stationary Solowian-industrial equilibrium – this is why I index value functions by time. Further, I introduce institutional market arrangements that do not allow individuals to perfectly insure risk at no cost which represent, perhaps, an accurate description of underdeveloped economies. In this context, I build an incomplete markets version of the hybrid OLG model in Santaeulàlia-Llopis (2007) – see also Hong and Ríos-Rull (2007). Households consist of families with at most three overlapping generations. Young adults of a z-type family at period t solve

$$V_t^y(z,a) = \max_{c\geq 0, x'\in A, s_k\in[0,1]} u_z^y(c) + \beta \sum_{z'\in Z} \Gamma\left(z'|z\right) \{\pi\, V_{t+1}^o(z',a') + (1-\pi)\, V_{t+1}^y(z',a')\} \quad (3)$$

subject to a budget constraint that for the sake of expositional brevity I simplify here as [19]

$$c + x' = w_t\, \epsilon_z + (1 + r_t - \delta)a$$

The household state space is the demographic and health status of all of its members, z, and its wealth, a. Households choose consumption, c and next period's wealth, x' - notice this is not a' because households may be subject to marriage and divorce. Rules $a'(x', x^{*'})$ define how family wealth changes in case of marital reshuffling. V_t^y is the value function of young adults, u_z^y is the utility function for young adults, and V_t^o is the value function of old adults. Households supply labor inelastically, but not all hours across individuals are the same, this way, $\epsilon_z = \sum_{z^{ig}} \epsilon_{z^{ig}}$, where $\epsilon_{z^{ig}}$ represents individual efficiency units of labor of individual of age i, sex g, and health status z^{ig} - which we will also condition on the family vector z (for example, married individuals earn more than single individuals). One can understand this loss in efficiency units of labor as a loss in human capital that we could further model explicitly.

Equilibrium. There is a requirement that agents decisions are consistent with their understanding of the evolution of the economy. From their point of view this includes not only the evolution of the epidemics and family composition, but also the prices they face and an assessment of the wealth of prospective spouses. A stationary equilibrium (one with constant rates of return, wage rates and savings) can be easily defined and solved. However, our central interest is the process of development and for this the evolution of the population and of savings have to be jointly determined. This requires the non stationary notion of equilibrium, that for non stationary population environments (but still quite different from mine) has been defined for example in Storesletten (2000) or Ríos-Rull (2001).

[19] For example, in Parente and Prescott (2005) the capital income would take the following form in equilibrium: $(1 + r_t - \delta)a = \left(\left(1 + r_t^K - \delta\right) s_k + \frac{q_t + r_t^L}{q_{t-1}}(1 - s_k)\right) a$. Where r_t^K is the return on capital, r_t^L is the return on land, q_t is the price of land in consumption units and s_K is the share of current wealth allocated to capital - an additional trivial choice for the household, since households will optimally chose that share such that the returns on capital and land equalize.

Calibration. In order to compute and project the population model I described above I need to obtain in very much detail the rates that compose the population transition matrix Γ – the most important piece of the calibration process in this model. These are mortality rates, fertility rates, marriage rates, divorce rates, HIV infection rates and AIDS progression rates for each individual by his/her age, sex, marital status, health status and the family composition where he/she belongs to. I calibrate the population projection matrix using transition frequency data from the last two waves of the Malawi Diffusion and Ideational Project data set, (MDICP) [20], representative of rural Malawi. This is a unique panel data set where individuals and their families are followed in terms of health and economic variables, including the HIV status of each family member such as spouses. This way, the rates in Γ can be computed by recording the state of individuals at time t and then returning to measure their fate at time $t+1$. Notice that in order to compute these rates we need two data points. To start with, I will use the two last waves of the MDICP data set, MDICP-2006 and MDCIP-2008. These have information about the HIV status – hence, HIV-infection rates – but not AIDS status. I plan to incorporate CD4 cells counts or information on the HIV load of those infected for the whole sample in the next wave, MDCIP-2010, to obtain AIDS progression rates. [21]

Algorithm. The problem above represents a computational challenge for two reasons. Firstly, I am solving a heterogeneous agents economy along a development path that represents a non-stationary environment - an economic transition from a stationary Malthusian-agricultural regime to a stationary Solowian-industrial regime. This means that in order to solve their maximization problem, young adults need to know the evolution of the distribution of wealth – an endogenous object – in order to forecast prices. In this context, I am applying a solution method technically similar to Krusell and Smith (1998) who solve analogous economies with heterogeneous agent models where the non-stationarity is generated by aggregate fluctuations. Secondly, due to marital reshuffling - marriage, divorce and remarriage - individuals need to forecast the wealth of prospective spouses, $x^{*'}$, that is, agents need to know the distribution of assets by agent's types. [22]

3 Thought Experiment and Policy Evaluation

The thought experiment goes as follows:

1. I construct a population process – formally, a population projection matrix model – able to capture the main margins through which AIDS impacts families and their members: mortality rates, birth rates, divorce/marriage rates, *HIV-infection* rates and *AIDS-progression* rates (all by sex, age, marital and health status). All these rates are parameter elements in the projection matrix. The population vector carries a total of $64(N+1)$ types of families, where N is the maximum number of children per family.

[20] See `www.malawi.pop.upenn.edu` with public access to the data.

[21] Instead, if we knew the next stable population (say, in 200 years ahead), we could back out the elements of the population matrix. This is not my case.

[22] In a bit more of detail, the Euler equation derived from (3) is a second order difference - and functional – equation in x'. Since we know function x'' at a final Solowian period T (stationary equilibrium with stationary distribution of assets), we can solve for x' backwards. The second boundary point is the stationary Malthusian regime at some initial period. In all, for each period t we have to find a solution for the function $x'(z, a)$ evaluated at every family state z and wealth state a.

2. I calibrate the population projection matrix to Malawi – a country that suffers from a mature AIDS epidemic (with a HIV prevalence of 10.5%) – using panel data collected by the Malawi Diffusion and Ideational Change Project.

3. I incorporate the above population model into a non-stationary theory of economic development that reproduces income per capita paths together with the industrialization process- a structural shift from a Malthusian-agricultural regime to a Solowian-industrial regime. This builds a structural relationship between the population margins that AIDS affects, – hence, the margins that RH/FP prevention policies that target *HIV-infection* and ARTs treatment policies that target *AIDS-progression* can alter – and the economic development path

4. I project an initial population distribution of Malawi using the population projection matrix under different AIDS and no-AIDS scenarios.

5. I solve for the economic development path under both AIDS and no-AIDS scenarios.

6. I use the model as a diagnostic device to investigate how much each AIDS margin that alters populations matters for development in terms of consumption per capita, the agricultural share of output and wealth inequality (shutting channels one by one).

Integrated RH/FP and AIDS Policy Evaluation.

This is the most important piece of the paper. I compare the alternative economic development paths generated by a set of alternative AIDS-related policies: some integrated RH/FP and AIDS policies that target reductions in *HIV-infection* rates and other ARTs treatment policies that target reductions in *AIDS-progression* rates. Each of these policies alters in a very different manner the fate of individuals, the composition of the families they belong to and, in turn, the demography of the whole society. Finally, given the structural relationship between population and economic development that I model here, each of these AIDS-related policies will, in turn, have different implications for economic development. The polices can be mainly summarized by appropriately modifying parameters of the population projection matrix:

1. Integrated RH/FP and AIDS policies that target reductions in young adults *HIV-infection* rates. The population matrix has parameters that represent adult infection rates of different individuals – by age, sex, marital status, and family composition. It is very easy then to see how percentage changes in these infection rates may change the development path of an economy. We can think of changes in these infection rates as implementations of RH/FP policies that enforce, for example, the use of condoms, circumcisions, treatment of genital soars or abstention that have been successful in Uganda.

2. Integrated RH/FP and AIDS policies that target reductions in mother-to-child *HIV-infection* rates. The population matrix has parameters that represent mother-to-child transmission in terms of the mortality rates of children of infected versus non-infected mothers. We can think of changes in those parameters as an implementation of reproductive health policies. An extreme example would assume that we can bring the reproductive health system of the U.S. or Europe to Malawi. This requires setting the mortality rates of children of infected mothers equal to the children of non-infected mothers.

3. ARTs treatment policies that target reductions in *AIDS-progression* rates. We can extend the lives of the individuals in the model by providing universal access to ARTs. To do so we

can decrease the *AIDS-progression* rates and, in turn, mortality rates – both, parameters in the population matrix – of infected individuals. We may also link such a decrease in mortality rates to some individual economic cost in the household budget constraint.

4. Finally, we can also evaluate policies that support the fosterhood and care of AIDS orphans. This would require some further development of the budget constraint.

The contribution of this research is twofold. First, the construction of a population model that allows for projections of population paths that separately identify *HIV-infections* and *AIDS-progressions*. In addition, the population model has the novelty that it builds on a family context where marriage/divorce rates are also affected by the AIDS versus no-AIDS environment, a margin that can seriously affect saving rates of an economy as AIDS creates more and more single-poor households, but that UNAIDS does not take into account when building its population projections (see Caldwell (2000)). Second, to the best of my knowledge, this is the first analysis that will provide aggregate economic effects of integrated RH/FP and AIDS-related policies. Moreover, this framework allows for a comparison, in terms of economic outcomes, between RH/FP policies focused on prevention of *HIV-infections* and ARTs policies focused on treatment of *AIDS-progressions*.

By the end of this research project, I expect have economic arguments that may suggest that we should rethink current U.S. (and other private and public donors) AIDS policies, perhaps, calling for a shift of new funds towards integrated RH/FP policies that target reductions in *HIV-infection* rates that may replicate the success of Uganda in other SSA countries such as Malawi.

References

Baily, M., F. Bastos, and K. Desai (2005): "Changes in the Transmission Dynamics of the HIV Epidemic After the Wide-Scale Use of Antiretroviral Therapy Could Explain Increases in Sexually Transmitted Infections: Results from Mathematical Models," *Sexually Transmitted Diseases*, 31, 100–113.

Bloom, D., D. Canning, and J. Sevilla (2002): *The Demographic Dividend: A New Perspective on the Economic Consequences of Population Change*. RAND Corporation.

Bracher, M., G. Santow, and S. C. Watkins (2004): "Assessing the Potential of Condom Use to Prevent the Spread of HIV: A Microsimulation Study," *Studies in Family Planning*, 35(1), 48–64.

Caldwell, J. (2000): "Rethinking the African AIDS Epidemic," *Population and Development Review*, 26, 117–135.

Galor, O., and D. Weil (2000): "Population, Technology, and Growth: From Malthusian Stagnation to the Demographic Transition and Beyond," *American Economic Review*, 90, 806–828.

Gollin, D., S. L. Parente, and R. Rogerson (2004): "Farm Work, Home Work, and International Productivity Differences," *Review of Economic Dynamics*, 7(4), 827–850.

Hansen, G. D., and E. C. Prescott (2002): "Malthus to Solow," *American Economic Review*, 92(4), 1205–1217.

Hong, J. H., and J.-V. Ríos-Rull (2007): "Social Security, Life Insurance and Annuities for Families," *Journal of Monetary Economics*, 54(1), 118–140.

Jamison, D. T., R. G. Feachem, M. W. Makgoba, E. R. Bos, F. K. Baingana, K. J. Hofman, and K. O. Rogo (eds.) (2006): *Disease and Mortality in Sub-Saharan Africa*. The International Bank for Reconstruction and Development/The World Bank.

Kalemli-Ozcan, S. (2006): "AIDS, Reversal of the Demographic Transition and Economic Development: Evidence from Africa," NBER Working Papers 12181.

Katz, M., S. Schwarcz, and T. Kellog (2002): "Impact of Highly Active Antiretroviral Treatment on HIV Seroincidence among Men Who Have Sex with Men," *American Journal of Public Health*, 92, 388–394.

Keyfitz, N., and H. Caswell (eds.) (2005): *Applied Mathematical Demography*. Springer.

Krusell, P., and A. Smith (1998): "Income and Wealth Heterogeneity in the Macroeconomy," *Journal of Political Economy*, 106, 867–896.

Lucas, R. E. (1988): "On the Mechanics of Economic Development," *Journal of Monetary Economics*, 22, 3–42.

Manuelli, R. E., and A. Seshadri (2005): "Human Capital and the Wealth of Nations," Working Paper.

Okware, S., J. Kinsman, S. Onyango, A. Opio, and P. Kaggwa (2005): "Revisiting the ABC Strategy: HIV Prevention in Uganda in the Era of Antiretroviral Therapy," *Postgraduate Medical Journal*, 81, 625–628.

Oster, E. (2007): "HIV and Sexual Behavior Change: Why Not Africa?," NBER Working Paper Number 13049.

Parente, S. L., and E. C. Prescott (2005): "A Unified Theory of the Evolution of International Income Levels," in *Handbook of Economic Growth*, ed. by P. Aghion, and S. Durlauf, vol. 1, chap. 21, pp. 1371–1416. Elsevier.

Preston, S. H., P. Heuveline, and M. Guillot (2000): *Demography: Measuring and Modeling Population Processes*. Wiley-Blackwell.

Reniers, G. (2008): "Marital Strategies for Regulating Exposure to HIV in Rural Malawi," *Demography*, 45(2), 417–438.

Ríos-Rull, J.-V. (2001): "Population Changes and Capital Accumulation: The Aging of the Baby Boom," *Advances in Macroeconomics, The B.E. Journals in Macroeconomics*, 1(7).

Santaeulàlia-Llopis, R. (2007): "Aggregate Effects of AIDS on Development," mimeo, University of Pennsylvania.

Smith, K. P., and S. C. Watkins (2005): "Perceptions of Risk and Strategies for Prevention: Responses to HIV/AIDS in Rural Malawi," *Social Science and Medicine*, 60, 649–660.

Stanecki, K. A. (2004): "The AIDS Pandemic in the 21st Century," U.S. Census Bureau, International Population Reports, WP/02-2.

Storesletten, K. (2000): "Sustaining Fiscal Policy Through Immigration," *Journal of Political Economy*, 108(2), 300–323.

UNAIDS (2006): *Report on the Global AIDS Epidemics 2006*.

Williamson, J. G. (1998): "Growth, Distribution, and Demography: Some Lessons from History," *Explorations in Economic History*, 3, 241–271.

Young, A. (2005): "The gift of the dying: The tragedy of AIDS and the welfare of future African Generations," *Quarterly Journal of Economics*, 120(2), 423–466.

Zaba, B., and S. Gregson (1998): "Measuring the Impact of HIV on Fertility in Africa," *AIDS*, 12(1), 41–50.