INTERNATIONAL FOOD
POLICY RESEARCH INSTITUTE
sustainable solutions for ending hunger and poverty

Supported by the CGIAR

IFPRI Discussion Paper 00864

May 2009

HIV/AIDS, Growth and Poverty in KwaZulu-Natal and South Africa

Integrating Firm-Level Surveys with Demographic and Economywide Modeling

James Thurlow

Gavin George

Jeff Gow

Development Strategy and Governance Division

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

The International Food Policy Research Institute (IFPRI) was established in 1975. IFPRI is one of 15 agricultural research centers that receive principal funding from governments, private foundations, and international and regional organizations, most of which are members of the Consultative Group on International Agricultural Research (CGIAR).

FINANCIAL CONTRIBUTORS AND PARTNERS

IFPRI's research, capacity strengthening, and communications work is made possible by its financial contributors and partners. IFPRI receives its principal funding from governments, private foundations, and international and regional organizations, most of which are members of the Consultative Group on International Agricultural Research (CGIAR). IFPRI gratefully acknowledges the generous unrestricted funding from Australia, Canada, China, Finland, France, Germany, India, Ireland, Italy, Japan, Netherlands, Norway, South Africa, Sweden, Switzerland, United Kingdom, United States, and World Bank.

AUTHORS

James Thurlow, International Food Policy Research Institute
Research Fellow, Development Strategy and Governance Division
Email: j.thurlow@cgiar.org

Gavin George, University of KwaZulu-Natal
Senior Research Fellow, Health Economics and HIV/AIDS Research Division

Jeff Gow, University of Southern Queensland
Associate Professor

Notices

[1] Effective January 2007, the Discussion Paper series within each division and the Director General's Office of IFPRI were merged into one IFPRI–wide Discussion Paper series. The new series begins with number 00689, reflecting the prior publication of 688 discussion papers within the dispersed series. The earlier series are available on IFPRI's website at www.ifpri.org/pubs/otherpubs.htm#dp.

[2] IFPRI Discussion Papers contain preliminary material and research results, and have been peer reviewed by at least two reviewers—internal and/or external. They are circulated in order to stimulate discussion and critical comment.

Contents

List of Tables

List of Figures

ACKNOWLEDGMENTS

We are grateful to Mark Colvin and Cherie Cawood for managing the firm-level survey and The Global Fund for HIV/AIDS, TB and Malaria for funding this study. [*]

[*] **Additional author affiliations**
James Thurlow
Visiting Fellow, Development Economics Research Group, University of Copenhagen
Jeff Gow
Research Associate, Health Economics and HIV/AIDS Research Division, University of KwaZulu-Natal

ABSTRACT

This paper estimates the economic impact of HIV/AIDS on KwaZulu-Natal (KZN) and the rest of South Africa (RSA). We extend previous studies by employing an integrated analytical framework that combines the following: firm-level surveys of workers' HIV prevalence by sector and occupation; a demographic model that produces both population and workforce projections; and a regionalized economywide model linked to a survey-based micro-simulation module. This framework permits a full macro-microeconomic assessment. The results indicate that HIV/AIDS greatly reduces annual economic growth, mainly by lowering the long-term rate of technical change. However, the impacts on income poverty are small, and inequality is reduced by HIV/AIDS. This is because high unemployment among low-income households minimizes the economic costs of increased mortality. In contrast, slower economic growth hurts higher-income households despite the lower prevalence of HIV among these households. We conclude that the increase in economic growth achieved through addressing HIV/AIDS is sufficient to offset the population pressure this move will place on income poverty. Moreover, incentives to mitigate HIV/AIDS lie not only with poorer infected households, but also with uninfected higher-income households. Our findings reveal that HIV/AIDS will place a substantial burden on future economic development in KZN and RSA, confirming the need for policies to curb the economic costs of this pandemic.

Keywords: HIV/AIDS, growth; poverty, KwaZulu-Natal, South Africa

1. INTRODUCTION

South Africa has one of the highest HIV prevalence rates in the world, and KwaZulu-Natal (KZN) is the most highly afflicted province in South Africa. Recent estimates indicate that 26.4 percent of KZN’s working-age population is HIV-positive, compared to 15.9 percent in the rest of the country (see Matthews et al., 2008). Unemployment and income poverty in KZN are also much higher than the national average, with a third of KZN’s population living below the US$2-a-day poverty line and two-fifths of the workforce unemployed (Hoogeveen and Özler, 2006; Bhorat and Oosthuizen, 2006). The long-term trends in KZN are equally bleak. Recent evidence indicates that economic growth continues to lag behind that of the rest of the country, and poverty is rising faster in KZN than in other provinces. A key challenge for reviving economic development in South Africa in general, and in KZN in particular, lies in understanding the constraints imposed by HIV/AIDS on future economic growth and poverty reduction.

Numerous studies estimating the micro-level impacts of the pandemic (see Casale and Whiteside, 2006) confirm the severe detrimental effects imposed on infected individuals and their households. However, while household-level studies can capture detailed noneconomic impacts, they typically overlook systemic or economywide shocks from HIV/AIDS, which can have indirect or “second-round” consequences for both infected and uninfected population groups. Some studies have assessed the broader implications of HIV/AIDS for economic growth and employment in South Africa (see, for example, Arndt and Lewis, 2001). However, these macroeconomic studies were conducted when detailed micro-level data on prevalence rates for different sectors and occupations were not yet available. The present availability of information on HIV prevalence among firms and workers now permits a more accurate assessment of the consequences of the pandemic. Moreover, these micro-level estimates can support more integrated approaches for measuring socioeconomic outcomes.

In this paper, we estimate the growth and distributional impacts of HIV/AIDS on KZN and the rest of South Africa (RSA). First, we conduct a firm-level survey in four of KZN’s largest sectors. Second, information on workers’ HIV prevalence rates from the survey is used to calibrate an occupation-focused demographic model. Finally, the demographic projections are imposed on a regionalized dynamic computable general equilibrium (DCGE) model linked to a household survey-based micro-simulation model. This integrated macro-microeconomic framework permits a more robust, empirically based assessment of the impacts of HIV/AIDS. Section 2 briefly describes the survey and demographic projections. Section 3 outlines the methodology, paying particular attention to the links between the demographic and DCGE models. Section 4 discusses the results of the DCGE model and their implications for future socioeconomic development in South Africa. The final section summarizes our findings.

2. DEMOGRAPHIC IMPACTS OF HIV/AIDS IN SOUTH AFRICA

The first stage of our analysis combines two demographic models.
[1] The first model estimates provincial population projections for different population groups. Based on these results, the second model estimates workforce projections by occupational group. The parameters of the second demographic model are calibrated to HIV prevalence rates obtained from a firm-level survey of workers. This section first describes the population projections and HIV prevalence profile, and then discusses the firm-level survey and workforce projections.

Population Projections

The provincial version of the ASSA-2003 model from the Actuarial Society of South Africa (ASSA, 2005) was used to estimate overall population projections for KZN and RSA. The model produces annual population estimates with and without the effects of HIV/AIDS for the period 1985-2025. The ASSA model disaggregates the total population by province, gender, racial group (African, Asian, Colored and White) and one-year age intervals. In the model, HIV is spread via heterosexual sexual activity amongst adults, who are divided into risk groups according to sexual behavior. The calibration of the model is based on epidemiological and medical research, population census data, and HIV prevalence data from antenatal clinic surveys and mortality statistics. Table 1 provides a profile of HIV prevalence for the year 2002, which is utilized as the base year for our economic analysis in later sections.

Table 1. HIV prevalence among working-age adults in South Africa, 2002

Population group	Gender	Age cohort	Population (millions)		HIV prevalence (%)	
			RSA	KZN	RSA	KZN
National	Both	All	35,252	9,250	**8.7**	**13.4**
Africans	Male	20-34	3,695	990	**19.6**	**30.6**
		35-49	2,241	507	**24.8**	**41.3**
		50-64	961	236	**11.9**	**21.4**
	Female	20-34	3,820	1,088	**29.8**	**43.3**
		35-49	2,430	655	**16.2**	**27.3**
		50-64	1,141	325	**1.6**	**3.0**
Other races	Male	20-34	995	172	**1.8**	**1.5**
		35-49	875	160	**2.3**	**2.2**
		50-64	521	108	**0.6**	**0.7**
	Female	20-34	1,011	174	**3.9**	**3.6**
		35-49	924	170	**3.2**	**3.0**
		50-64	571	120	**0.4**	**0.4**

Source: Own calculations using estimates from ASSA (2005) and Matthews et al. (2008).

HIV prevalence is concentrated in working-age Africans, especially younger females (20-34 years) and slightly older males (35-49 years). The prevalence for other racial groups is considerably lower for all age cohorts. Moreover, among Africans, the prevalence of HIV/AIDS is heavily concentrated within KZN; this pattern does not exist for other races. Given the large numbers of individuals contained within the African and KZN populations, it is clear that this province and population group form the epicenter of South Africa's HIV pandemic. The effects of this concentration are evident in the population projections from the ASSA model (see Table 2).

[1] For a detailed description of the demographic model and projections see Matthews et al. (2008).

Table 2. Demographic projections, 2002-2025

		Population (millions)		Prevalence rate (%)	AIDS-sick rate (%)
		No AIDS	AIDS		
KZN	1990	3.54	3.54	0.39	0.00
	1995	4.13	4.12	7.35	0.11
	2000	4.64	4.57	23.18	1.28
	2005	5.25	4.87	27.95	3.49
	2010	5.90	5.06	27.59	3.80
	2015	6.52	5.24	26.85	3.79
	2020	7.16	5.43	26.49	3.70
	2025	7.70	5.52	26.17	3.70
RSA	1990	13.51	13.51	0.16	0.00
	1995	16.16	16.16	3.42	0.05
	2000	18.53	18.40	13.16	0.63
	2005	20.96	20.15	18.06	1.92
	2010	23.27	21.35	18.99	2.26
	2015	25.22	22.09	18.74	2.50
	2020	27.10	22.71	18.18	2.50
	2025	28.73	23.12	17.78	2.43

Source: Own calculations using estimates from ASSA (2005).

The long-term implications of HIV/AIDS for population growth are pronounced. Without its effects, the adult population of South Africa is predicted to reach 36.4 million by 2025. AIDS deaths reduce this adult population by 7.8 million people, which is more than a quarter of the expected population in 2025. The predicted loss of life in KZN is even more staggering, with the adult population depleted by two-fifths due to HIV/AIDS. The pandemic is, however, expected to peak around 2010, with HIV prevalence rates beginning to fall and AIDS-related sickness and death declining after 2020. Despite the fact that the pandemic is predicted to “turn the corner,” its scale and concentration among working-age adults will have grave implications for South Africa’s workforce.

Firm-Level Survey and Workforce Projections

Previous studies relied on population projections to estimate the economic consequences of HIV/AIDS in South Africa. As part of our study, Matthews et al. (2008) developed an AIDS Projection Model (APM) to estimate the size of the workforce in the presence and absence of HIV/AIDS. The model distinguishes among three occupation levels (managers, skilled workers, and laborers), genders, two racial groups (African and Other), and three age cohorts (20-34, 35-49 and 50-64). The APM is a demographic model, and therefore cannot predict changes in workforce composition (i.e., shifts in sectoral employment patterns driven by economic forces). This is the domain of the economywide model. However, the APM does combine the population projections of the ASSA model with HIV test data from the firm-level survey, and uses this information to predict the impact of HIV/AIDS on the workforce size for different occupational groups.[2] It therefore provides the critical link between the population projections described above and the economic analysis introduced in the next section.

[2] The changing sectoral composition of employment is endogenously determined by the DCGE model.

The calibration of the APM was based on the firm-level survey data collected during our study. Anonymous HIV tests were conducted at 15 companies in four economic sectors: agriculture, manufacturing, tourism, and transport.[3] These are key sectors of the South African economy. Together they comprise 59.1 and 44.7 percent of KZN and RSA's gross domestic product (GDP), respectively, and 55.8 and 49.1 percent of their labor employment, respectively. Of the 6197 workers that we surveyed, only 4464 successfully completed the questionnaire. Our study sample had an overall HIV prevalence rate of 16.7 percent, with a 95 percent confidence interval of ± 1.1 percent. Table 3 presents the prevalence rates for male African workers by sector and occupation.[4]

Table 3. HIV prevalence rates for male Africans by occupation, 2002

Sector	Age cohort	Occupation groups: Managers	Skilled	Laborers
Agriculture	20-34	33.9	29.8	35.0
	35-49	37.8	32.6	38.2
	50-64	16.8	16.3	19.1
Manufacturing	20-34	22.2	24.9	31.1
	35-49	24.7	27.2	33.9
	50-64	0.0	14.0	17.6
Tourism	20-34	29.9	34.1	37.6
	35-49	33.8	37.3	40.9
	50-64	0.0	18.4	20.0
Transport	20-34	13.4	20.5	32.5
	35-49	14.3	22.4	35.1
	50-64	7.5	11.3	17.9

Source: Own calculations using estimates from Matthews et al. (2008).

The survey reveals considerable heterogeneity across workers. Prevalence rates are typically highest for laborers (i.e., unskilled workers) within the agriculture and tourism sectors. They are lowest for managers and professionals, with the exception of agriculture, where prevalence rates are similar for all three occupational groups. Prevalence is significantly higher for the middle age cohort, which is consistent with observed national trends. These survey results clearly indicate that it is inappropriate to make broad generalizations about the sectoral and occupational trends of HIV prevalence. Therefore, the inclusion of an empirically-calibrated APM that produces occupation-based workforce projections greatly enhances the accuracy of our economic analysis compared to those in previous studies. It also provides a crucial link between the economic growth impacts of HIV/AIDS and its effects on employment, poverty and inequality. The next section describes how these demographic projections are incorporated within the economic modeling.

[3] The 15 companies were surveyed over three years: two in 2005, 11 in 2006, and two in 2007. For convenience, we treat all survey results as reflecting HIV prevalence in 2006.

[4] The firm-level survey-based estimates of HIV prevalence are "smoothed" to account for the wider confidence intervals seen for specific subgroups of the sample (see Matthews et al., 2008).

3. ESTIMATING THE ECONOMIC IMPACTS OF HIV/AIDS

HIV/AIDS affects economic growth and poverty via various impact channels. At the household level, a wide range of factors influence poverty; these include vulnerability from deteriorating livelihoods, heightened stigmatism, fragmentation of social networks, and lower investments in human capital and nutrition. These household-level effects need to be aggregated for us to estimate the overall impact of the pandemic. Moreover, while households are directly affected by HIV/AIDS, there are also broader implications for the economy as a whole. In our macro-microeconomic assessment, we account for not only households but also other actors and institutions, such as firms, markets and the government. However, broadening our analysis necessarily excludes some difficult-to-measure household-level impacts. Therefore, given our focus on economic growth, we concentrate on the income dimensions of poverty. Ultimately, we identify five main impact channels for HIV/AIDS: population growth, labor supply, labor productivity, total factor productivity, and savings and investment. This section describes how these impact channels are captured in the economywide model

Simplified General Equilibrium Model

Table 4 presents the equations of a simple closed-economy computable general equilibrium (CGE) model illustrating how HIV/AIDS affects the economic outcomes examined in our analysis. The model is recursive dynamic, and can therefore be separated into a static "within-period" component wherein producers and consumers maximize profits and utility, and a dynamic "between-period" component wherein the model is updated based on the demographic model and previous period results, thereby reflecting changes in population, labor supply, and the accumulation of capital and technology.

In the static component of the model, producers in each sector s and region r (i.e., KZN and RSA) produce a level of output Q in time period t by employing the factors of production F under constant returns to scale (exogenous productivity α) and fixed production technologies (fixed factor shares δ) (eq. [1]). Profit maximization implies that factor payments W are equal to average production revenues (eq. [2]). Labor supply L and capital supply K are fixed within a given time period, implying full employment of factor resources. Labor market equilibrium is defined at the regional level, so labor is mobile across sectors but wages vary by region (eq. [6]). National capital market equilibrium implies that capital is mobile across both sectors and regions, and earns a national rental rate (i.e., regional capital returns are equalized) (eq. [7]).

Factor incomes are distributed to households in each region using fixed income shares based on the households' initial factor endowments (eq. [3]). Total household incomes Y are then either saved (based on marginal propensities to save υ) or spent on consumption C (according to marginal budget shares β) (eq. [4]). Consumption spending includes a "subsistence" component λ that is independent of income and determined by household population H. Savings are collected in a national savings pool and used to finance investment demand I (i.e., savings-driven investment closure) (eq. [5]).[5] Finally, a single price P equilibrates national product markets, thus avoiding the necessity of modeling interregional trade flows (eq. [8]).[6]

[5] Nell (2003) empirically tests the causality between national savings and investment in South Africa, and confirms the appropriateness of a savings-driven investment closure.

[6] The model's numéraire is a consumer price index weighted by the aggregate household consumption basket.

Table 4a. Simplified CGE model equations

Static model equations			
Production	$Q_{srt} = \alpha_{srt} \prod_{f} a_{frt} \cdot F_{fsrt}^{\delta_{fsr}}$		**(1)**
Factor returns	$W_{frt} \cdot \sum_{s} F_{fsrt} = \sum_{s} \delta_{fsr} \cdot P_{st} \cdot Q_{srt}$		**(2)**
Income	$Y_{hrt} = \sum_{ft} \theta_{hf} \cdot W_{frt} \cdot F_{frt}$		**(3)**
Consumption	$P_{st} \cdot C_{hsrt} = \lambda_{hsr} \cdot P_{st} \cdot H_{hrt} + \beta_{hsr} \cdot (1 - v_{hr}) \cdot \left(Y_{hrt} - \sum_{hs} \lambda_{hsr} \cdot P_{st} \cdot H_{hrt} \right)$		**(4)**
Investment	$P_{st} \cdot I_{st} = \mu_{s} \cdot \sum_{hr} v_{hr} \cdot Y_{hrt}$		**(5)**
Labor market	$\sum_{s} F_{fsrt} = L_{frt}$	*f is labor*	**(6)**
Capital market	$\sum_{rs} F_{fsrt} = K_{ft}$ $\quad and \quad$ $W_{frt} = W_{fr't}$	*f is capital*	**(7)**
Product market	$\sum_{hr} C_{hsrt} + I_{st} = \sum_{r} Q_{srt}$		**(8)**
Dynamic equations and links to the demographic model			
Population	$H_{hrt} = \sum_{pga} H_{hpgart} \quad \text{where} \quad H_{hpgart} = sh_{hpgar} \cdot \frac{DH_{pgart}}{dh_{pgar}}$		(9)
Labor supply	$L_{frt} \approx \sum_{a} L_{pgaert} \quad \text{where} \quad L_{pgaert} = sl_{pgaert} \cdot \frac{DL_{pgaert}}{dl_{pgaer}}$	*f is labor*	(10)
Labor productivity	$a_{frt} = a_{frt-1} \cdot (1 + \gamma_{frt}) \quad \text{where}$		
	$\gamma_{frt} \approx \mu_{pgr} \cdot \left[(1 - DP_{pgert}) + 0.5 \cdot (DP_{pgert} - DA_{pgert}) + 0.2 \cdot DA_{pgert} \right]$	*f is labor*	(11)
Technical change	$\alpha_{srt} = \alpha_{srt-1} \cdot (1 + \varphi_{r})$		(12)
Capital supply	$K_{ft} = K_{ft-1} \cdot (1 - \pi) + \frac{P_{st-1} \cdot I_{st-1}}{\kappa}$	*f is capital*	(13)

Table 4b. Simplified CGE model variables and parameters

Subscripts			**Endogenous variables in CGE model**
f	Factors	*C*	Household consumption demand quantity
r	Regions	*F*	Factor demand quantity
s	Sectors	*I*	Investment demand quantity
t	Time periods	*K*	National capital supply
p	Population group (race)	*L*	Regional labor supply
g	Gender	*M*	Migration rate between regions r and r'
a	Age cohort	*P*	Commodity price
o	Occupation group	*Q*	Output quantity
Exogenous parameters		*W*	Average factor return
α	Total factor productivity (production shifter)	*Y*	Total household income
β	Household marginal budget share		**Projections from demographic model**
γ	Factor-specific productivity growth rate	*DH*	Population projection
δ	Factor input share parameter	*DL*	Labor supply projection
ε	Factor-specific productivity (input shifter)	*DP*	Predicted HIV prevalence rate
θ	Household share of factor income	*DA*	Predicted full-blown AIDS prevalence rate
κ	Base price per unit of capital stock		**Base-year (2002) stock estimates**
λ	Per capita subsistence consumption quantity	*sh*	Household population profile (household survey)
φ	Hick's neutral productivity growth rate	*sl*	Labor force profile (labor survey)
π	Capital depreciation rate	*dh*	Population profile (demographic model)
ρ	Investment commodity expenditure share	*dl*	Labor force profile (demographic model)
σ	Exogenous factor supply growth rate		
υ	Household marginal propensity to save		
μ	Exogenous labor productivity growth rate		

The model's variables and parameters are calibrated to observed data from a provincial social accounting matrix (SAM) that captures the initial equilibrium structure of the KZN and RSA economies in 2002.[8] The parameters are then adjusted over time to reflect demographic and economic changes, and the model is re-solved for a series of new equilibriums for the period 2002-2015. Two simulations are conducted – "AIDS" and "No AIDS" – and the differences in the final values of variables are interpreted as the impacts of HIV/AIDS.

Dynamic Impacts of HIV/AIDS

Between periods, household populations *H* increase at rates determined by the demographic model (eq. [9]). Individual-level population projections *DH* are estimated for each region *r*, population group *p*, gender *g* and age cohort *a*, and are then compared to predicted population levels *dh* in the base year

[8] A social accounting matrix (SAM) is a consistent database capturing all monetary flows in an economy in a given year. It contains information on the production technologies and demand structures of detailed sectors, regions and households, as well as government revenues/expenditures and foreign receipts/payments. Various datasets were used to build the 2002 provincial SAM for South Africa, including national accounts, the 2000 income and expenditure survey, the 2002 labor force survey; and the South African Standard Industrial Database (Quantec, 2007). The income and expenditure data were reconciled using cross-entropy estimation. For more information on the SAM, see Thurlow (2005).

2002.[9] This ratio is multiplied by the observed demographic composition *sh* of each household group *h* in the CGE model to arrive at household-level population time-series for 2002-2025.[10] Similarly, labor supplies are based on demographic projections for occupation-based skill groups (eq. [10]).[11] In the DCGE model, the population and labor supply variables draw directly on the demographic projections *DH* and *DL* to capture the first two impact channels of HIV/AIDS. By increasing mortality, the pandemic reduces consumer demand and the productive capacity of the economy, which is likely to have adverse effects on economic growth.

The third impact channel is the effect of morbidity on workers' productivity. This is captured in (eq. [11]), where the labor productivity growth rate ε depends on the exogenous productivity growth μ adjusted for the share of the population that is HIV-positive *DP* or AIDS-sick *DA* (i.e., suffering from full-blown AIDS).[12] Under the "No AIDS" scenario, *DP* and *DA* are zero and labor productivity grows at μ. This growth rate is lower under the "AIDS" scenario, because we assume that HIV-positive workers are half as productive as uninfected workers and that AIDS-sick workers are a fifth as productive, due to decreased on-the-job productivity and more days spent absent from work.[13]

The fourth impact channel is the reduction in total factor productivity (TFP) caused by *systemic* shocks to the economy (eq. [12]). For example, AIDS morbidity and mortality reduces the productivity of uninfected workers by disrupting the production process. Moreover, the death of education and health professionals has long-term detrimental effects on the entire economic system. Unfortunately, this impact channel cannot be calibrated using the firm-level survey data or demographic model. Thus, we assume that AIDS reduces annual TFP growth φ by around half a percent per year. This is similar to the TFP losses used in other studies of South Africa and Botswana (Arndt and Lewis, 2001; Thurlow, 2006).
The final impact channel is the adverse effect on savings and investment (see Freire, 2002). HIV/AIDS increases households' healthcare spending and lowers spending on other products, such as food, shelter and clothing. As a coping strategy, households draw on assets or savings. Accordingly, it is assumed that an infected households' share of disposable income spent on health care increases by five percentage points and savings rates are reduced by the same amount (i.e., β and υ in eq. [4]). This lowers the overall level of savings and investment (eq. [5]). Investment from the previous period is then converted into new capital stocks using a fixed capital price κ (eq. [13]). This is added to previous capital stocks after applying a fixed rate of depreciation π. New capital is endogenously allocated to regions and sectors in order to equalize capital returns. The model therefore endogenously determines the national rate of capital accumulation and supply of capital *K*. If HIV/AIDS reduces national income, then it lowers the level of savings and investable funds in the economy, thereby reducing the rate of capital accumulation and further reducing long-term economic growth.

Extensions to the Full Model

The simplified model illustrates how HIV/AIDS affects economic outcomes in our analysis. However, the full model drops certain assumptions.[14] Constant elasticity of substitution (CES) production functions allow factor substitution based on relative factor prices (i.e., δ is no longer fixed). The model identifies 25 sectors in KZN and RSA.[15] Intermediate demand in each sector (excluded from the simple model) is

[9] The year 2002 is an appropriate base for both the "AIDS" and "No AIDS" scenarios, since it predates most of the main effects of HIV/AIDS on South Africa's working population (see Figure 1).

[10] Demographic compositions are drawn from the re-weighted 2000 Income and Expenditure Survey (StatsSA, 2001).

[11] The factor subscript *f* is a composite for a worker's population group *p*, gender *g*, and occupation *o*.

[12] Selected values of DP and DA for the entire population are given in the final two columns of Table 2.

[13] Although the prevalence rates are estimated by the demographic model, the impact of morbidity on worker productivity must be assumed, because few empirical studies have estimated worker productivity losses from HIV/AIDS. Given the findings from Fox et al. (2004), who studied tea pickers in Kenya, our assumptions may be an upper-bound estimate of productivity losses. However, as seen in the next section, this impact channel is found to contribute the least to the overall economic impact of HIV/AIDS.

[14] The full DCGE model is an extended version of the national model described in Thurlow (2005).

[15] The 25 sectors are mapped onto the four sectors in the firm survey. Most of the sectors in the DCGE model are in

determined by fixed technology coefficients. Regional labor markets are further segmented across race, gender, and three occupation-based skill categories. A nested demand system places skill levels above gender and age groups. All factors are assumed to be fully employed, and capital is immobile across sectors. New capital from past investment is allocated to regions/sectors according to profit rate differentials under a "putty-clay" specification.

The full model still assumes national product markets. However, international trade is captured by allowing production and consumption to shift imperfectly between domestic and foreign markets, depending on the relative prices of imports, exports and domestic goods. Since South Africa is a small country, world prices are fixed and the current account balance is maintained by a flexible real exchange rate (i.e., the price index of tradable-to-nontradable goods). Production and trade elasticities are econometrically estimated.

Households maximize a Stone-Geary utility function such that a linear expenditure system determines consumption and permits non-unitary income elasticities. The latter are drawn from Case (2000). Households are disaggregated across the following: two regions, the racial group of household head (i.e., African or Other), and 14 income groups (ten deciles with the top decile separated into five income groups). These household groups pay taxes to the government based on fixed direct and indirect tax rates. Tax revenues finance exogenous recurrent spending, resulting in an endogenous fiscal deficit. Finally, the model includes a micro-simulation module in which each household in the 2000 Income and Expenditure Survey (StatsSA, 2001) is linked to its corresponding representative household in the DCGE model. Changes in household-level real consumption spending on each commodity are passed down from the DCGE model to the household survey, where total per capita consumption and poverty measures are recalculated.

In summary, the full DCGE model captures the detailed sectoral and labor market structure of South Africa's economy as well as the linkages among production, employment and household incomes. Moreover, the results from the firm-level survey and demographic model are explicitly integrated within the economic analysis. Although not exhaustive, the five main impact channels captured by the DCGE model provide a reasonable approximation of the consequences of HIV/AIDS on growth, poverty and inequality.

---

manufacturing, but we assume similar prevalence rates for mining. Similarly, we assign the prevalence rates of the tourism sector to the retail trade sector, and the prevalence rates of the transport sector to the remaining service sectors.

4. RESULTS AND DISCUSSION

Two simulations are conducted to estimate the impact of HIV/AIDS during the period 2002-2025. The "AIDS" scenario captures the current growth paths of KZN and RSA, drawing on the demographic projections for population and labor supply, and observed trends for TFP and labor productivity growth.[16] Then, under the hypothetical "No AIDS" scenario, we adjust the demographic projections to capture the higher population, labor supply and productivity growth rates that would be seen in the absence of HIV/AIDS. In this section, we compare the results from these two simulations.

Growth and Employment

Tables 5 and 6 present the growth and employment results from the DCGE model. Given the demographic projections, HIV/AIDS reduces KZN's overall population growth rate from an average of 1.85 percent during 2002-2025 under the "No AIDS" scenario to 0.79 percent in the "AIDS" scenario. This is larger than the decline in the population growth rate for RSA due to the province's higher HIV prevalence. Similarly, the declines in the African population are substantially larger than those for other races due to the higher prevalence of HIV among Africans.

Table 5. Growth and poverty results, 2002-2025

	KwaZulu-Natal (KZN)			Rest of South Africa (RSA)		
	Initial, 2002	Annual growth (%)		Initial, 2002	Annual growth (%)	
		AIDS	No AIDS		AIDS	No AIDS
GDP (R billions)	171	2.84	4.44	872	3.04	4.46
GDP per capita (R)	18,464	2.03	2.54	24,723	2.23	2.88
Population (millions)	9,250	0.79	1.85	35,252	0.79	1.54
African	7,999	0.93	2.08	28,045	0.94	1.80
Other	1,252	-0.23	-0.03	7,207	0.17	0.37
Dependency ratio (pop / employ.)	4.86	5.05	4.98	4.41	4.40	4.31
African households	5.57	5.62	5.38	4.94	4.82	4.60
Other households	2.69	2.73	2.82	3.12	3.13	3.21
Total factor productivity	-	0.03	0.60	-	-0.04	0.50
Household savings rate (%)	1.76	1.40	3.51	0.50	0.40	1.00
Health spending share of income (%)	13.55	20.87	14.33	14.02	21.44	14.90
Poverty rates (%)						
Incidence of poverty (P0)	36.66	19.46	20.00	24.83	10.50	9.51
Depth of poverty (P1)	14.73	6.02	6.20	9.40	3.46	3.15
Severity of poverty (P2)	7.71	2.69	2.77	4.91	1.74	1.60
Number of poor people (thousands)	3,391	2,157	2,819	8,752	4,438	4,759
Number of AIDS deaths (thousands)	-	3,011	0	-	7,793	0

Source: Provincial DCGE model results.
Notes: Poverty is based on US$2- a-day poverty line (R161 per adult equivalent per month in 2000 prices).

[16] Demographic projections provide time-series estimates for *DH* (eq. [9]), *DL* (eq. [10]), *DP* and *DM* (eq. [11). Observed trends for 1990-2007 provide estimates of μ (eq. [11]), φ (eq. [12]), π and κ (eq. [13]). Together, these parameters define the exogenous dynamic component of the DCGE model. Static component parameters and behavioral elasticities are either econometrically estimated or drawn from the 2002 SAM.

Table 6. Labor market results, 2002-2025

	KwaZulu-Natal (KZN)			Rest of South Africa (RSA)		
	Initial, 2002	Annual growth (%)		Initial, 2002	Annual growth (%)	
		AIDS	No AIDS		AIDS	No AIDS
Employment (1000s)	1,902	0.63	1.75	7,988	0.81	1.64
African	1,436	0.90	2.24	5,677	1.05	2.11
Skilled	184	0.87	1.73	679	1.01	1.67
Semi-skilled	718	0.99	2.23	2,844	1.06	2.04
Low-skilled	534	0.78	2.43	2,154	1.05	2.33
Other	466	-0.31	-0.24	2,311	0.15	0.24
Labor productivity	-	1.80	1.92	-	1.80	1.88
African	-	1.80	2.02	-	1.80	1.95
Skilled	-	1.80	1.93	-	1.80	1.89
Semi-skilled	-	1.80	2.02	-	1.80	1.96
Low-skilled	-	1.80	2.10	-	1.80	2.00
Other	-	1.80	1.82	-	1.80	1.82
Wages (Rand)	75,511	3.09	4.05	96,054	2.94	3.93
African	59,219	2.48	2.88	91,944	2.67	3.33
Skilled	64,824	2.53	3.24	120,083	2.76	3.63
Semi-skilled	33,516	2.30	2.69	41,826	2.33	2.89
Low-skilled	20,098	2.63	1.86	21,979	2.74	2.33
Other	91,803	3.44	4.68	100,163	3.19	4.41

Source: Provincial DCGE model results.

The declines in labor supply caused by HIV/AIDS are larger than the declines in population growth (see Table 6). For example, the population growth rate falls by 1.06 percent in KZN while employment growth falls by 1.12 percent. This reflects the concentration of HIV infections among working age adults. Since employment growth exceeds population growth, the dependency ratio falls slightly under the "No AIDS" scenario, from 5.05 to 4.98. This is driven by African households, which are characterized by lower-skilled workers with higher HIV/AIDS prevalence rates, and are therefore more affected by the disease. Thus, part of the higher dependency ratio seen for African households is driven by HIV/AIDS, which reduces the African working-age population faster than it reduces the African population as a whole. The reverse is true for other racial groups, albeit only slightly.

High HIV prevalence and larger proportions of AIDS-sick people explain why HIV/AIDS has a more negative effect on labor productivity in KZN than in the rest of the country (see Table 6). Based on observed trends, labor productivity grows at 1.8 percent under the "AIDS" scenario. However, this is below the 1.92 percent that would have been achieved in KZN without AIDS-related morbidity and worker absences. Productivity losses from HIV/AIDS are largest for lower-skilled African workers due to their higher HIV prevalence. These variations in labor supply and productivity impacts underline the importance of differentiating among skill levels and occupation groups when estimating the macroeconomic impacts of HIV/AIDS.

Based on the results of other studies, we assume that HIV/AIDS reduces annual TFP growth by 0.5 percent per year (see the discussion in Section 3). The overall losses in TFP growth in the DCGE model are slightly larger due to endogenous shifts in resources towards more productive industries (see Table 5). This makes the economywide TFP growth rate about 0.6 percentage points higher under the "No AIDS" scenario. It should also be noted that the reported changes in the TFP growth rate are independent of the implied TFP changes caused by labor productivity improvements. Together, higher productivity and labor supply induce an expansion of gross domestic product (GDP); the average annual GDP growth rate in KZN increases from 2.84 percent under the “AIDS” scenario to 4.44 percent under the “No AIDS” scenario (i.e., HIV/AIDS lowers KZN’s annual GDP growth rate by 1.60 percent per year). This is greater than the negative impact of HIV/AIDS on the rest of South Africa’s GDP growth rate, which is reduced by 1.42 percent per year. Compounding these reductions in annual growth rates means that the KZN and RSA economies are projected to be 43 and 37 percent smaller, respectively, in 2025 than they would have been in the absence of HIV/AIDS.

Industrial Growth

Impacts differ by industry and region (see Table 7). Although the overall decline in economic growth due to HIV/AIDS is larger in KZN than in RSA, this is not the case for all individual sectors. The DCGE model captures the varying skill intensities of employment by sector and region from the 2004 labor force survey (StatsSA, 2005). This information indicates that the construction industry in KZN is more skill-intensive than that in RSA, with 18 percent of employment comprising low-skilled workers in KZN compared to 26 percent in RSA. Thus, by reducing the supply of lower-skilled workers, HIV/AIDS hampers the construction industry more in RSA than in KZN. Similarly, unskilled workers account for 22 percent of employment in RSA’s water utilities industry, compared to only 10 percent in KZN. Therefore, additional GDP growth in these industries is higher in RSA than in KZN under the “No AIDS” scenario.

Table 7. Change in industrial growth results, 2002-2025

	Point change in growth rate in “No AIDS” scenario [1]		Ratio of KZN to RSA growth rate changes (1) / (2)
	KZN (1)	RSA (2)	
All sectors (total GDP)	1.60	1.42	1.13
Agriculture	1.88	1.42	1.32
Mining	1.93	1.66	1.16
Food processing	1.74	1.40	1.24
Textiles & clothing	1.66	1.56	1.06
Wood products	1.46	1.46	1.00
Chemicals	1.22	1.47	0.83
Non-metal minerals	1.72	1.70	1.02
Machinery	1.53	1.61	0.95
Electrical machinery	2.28	1.67	1.37
Scientific equipment	1.64	1.41	1.16
Transport equipment	1.59	1.44	1.10
Other manufactures	1.55	1.53	1.01
Electricity	2.05	1.38	1.49
Water and gas	1.47	1.61	0.91
Construction	1.91	1.93	0.99
Trade services	1.82	1.47	1.23
Hotels & catering	1.64	1.45	1.13
Transport services	1.63	1.52	1.08
Communications	1.76	1.51	1.17
Financial services	1.89	1.53	1.24
Business services	1.95	1.49	1.31

Source: Provincial DCGE model results.

1. Percentage point change in annual growth rate between “AIDS” and “No AIDS”; Scenarios (i.e., not a percentage change).

Although HIV/AIDS has detrimental effects on industries in RSA, the majority of industries that are most severely hurt by the pandemic are in KZN. This is particularly true for agriculture in KZN, where the AIDS seroprevalence survey data and demographic modeling predict especially high HIV prevalence rates. Moreover, this impact on agriculture has negative downstream implications for food processing in KZN. Although the model does not capture rural-urban differences, the large increase in agriculture's growth rate under the "No AIDS" scenario suggests that the impacts of HIV/AIDS are likely to be more severe in rural areas. Had the model explicitly captured the higher HIV prevalence in rural areas, such outcomes would have been more pronounced.

Among the industries in KZN that are adversely affected by HIV/AIDS, the electrical machinery and electricity industries are most severely undermined. The 2002 supply-use table (StatsSA, 2004) (on which the DCGE is based) indicates that the electrical machinery sector is less capital-intensive than most other industries in the economy. Thus, this sector is more vulnerable to the reductions in labor supply caused by HIV/AIDS. Moreover, electrical machinery has a high income elasticity (1.23), which suggests that demand is particularly sensitive to changes in incomes. In contrast, other light manufacturing industries (e.g., food products and textiles) have lower income elasticities. As a result, the fall in national income caused by HIV/AIDS generates larger declines in demand for electrical machinery than for food products or textiles. Finally, most jobs in KZN's electrical machinery industry are for lower-skilled workers, who are most affected by HIV/AIDS. Collectively, these characteristics of the electrical machinery industry explain the considerable acceleration of its growth under the "No AIDS" scenario.

The water utilities industry is also less skill-intensive in KZN than in RSA. However, unlike the electrical machinery industry, the water utilities industry is far more capital-intensive than most of the other industries in the economy. Thus, it is less the decline in labor supply that undermines growth in this industry, but rather the negative consequences of HIV/AIDS for investment and capital accumulation. Our model results indicate that the share of investment in GDP is 2.1 percent lower under the "AIDS" scenario. While most of this decline in investment is due to the slowdown in economic growth caused by HIV/AIDS, about 28 percent of the decline results from lower household savings (see Table 5). Thus, the deceleration in economic growth, especially in certain sectors, is driven by the indirect macroeconomic impacts of HIV/AIDS rather than by its direct impact on population and labor supply.

Poverty and Inequality

The impact of HIV/AIDS on income poverty is small (see Table 5). Poverty is measured using the US$2 per day poverty line (which was equal to R161 per person per month in 2000 – the survey year for the micro-simulation module). The model results indicate that, without HIV/AIDS, the incidence of poverty (or poverty headcount) would be only slightly lower in RSA, at 9.51 under the "No AIDS" scenario compared to 10.50 under the "AIDS" scenario. Moreover, the poverty headcount in KZN would be virtually unchanged (or slightly higher).[17] These impacts are small because the net effect of HIV/AIDS on income poverty depends on two opposing factors. On the one hand, the drop in the working-age adult population and the rise in dependency ratios reduce households' incomes. On the other hand, poverty is based on per capita expenditures, which may increase if the decline in household populations exceeds the loss of income. The overall poverty impact therefore depends on which of the two factors dominate.

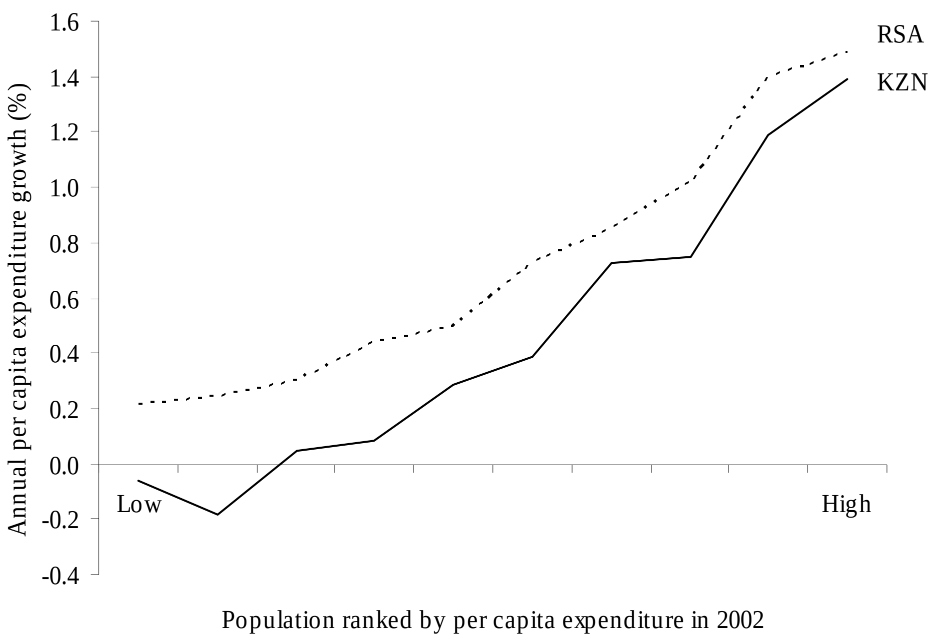
It is surprising that the model predicts both slightly higher poverty and falling dependency ratios in KZN under the "No AIDS" scenario. We find that poverty remains virtually unchanged because the decrease in wages, which is caused by labor demand constraints, implies that household incomes increase more slowly than population growth (see Table 6). Falling wages are more pronounced for lower-skilled African workers, whose wage growth rate falls from 2.63 percent under the "AIDS" scenario to 1.86 percent under the "No AIDS" scenario. In contrast, higher-skilled workers have lower HIV prevalence rates and benefit more from faster economic growth (i.e., their wages rise). Thus, the structural

[17] The poverty outcomes are extremely sensitive to changes in the definition of the poverty line. This is especially true for KZN, since its growth incidence curve crosses the x-axis almost at the final-year poverty rate (see Figure 1). Greater attention should therefore be paid to the distributional impacts of HIV/AIDS.

constraints that contribute to high unemployment in South Africa remain even in the absence of HIV/AIDS. More specifically, our results indicate that the KZN and RSA economies would continue to become more capital- and skill-intensive over time even if the supply and productivity of lower-skilled workers were not undermined by HIV/AIDS.

It is also an apparent contradiction that poverty remains virtually unchanged in KZN under the "No AIDS" scenario even though per capita GDP growth accelerates by 0.5 percent (see Table 5). This finding underlines the importance of considering industry- and household-level details that are not captured by aggregate growth models. Aggregate GDP and consumption measures hide the distributional changes caused by HIV/AIDS. Figure 1 presents the "growth incidence curves" for KZN and RSA. These curves show the change in the growth rate of annual per capita expenditure for each individual in the population, ranked by initial expenditure level.

Figure 1. Regional growth incidence curves, 2002-2025



Source: Provincial DCGE model results.

The mean of both regions' curves is positive, reflecting the increases in aggregate per capita income under the "No AIDS" scenario. However, the growth incidence curves are upward-sloping, indicating that lower-income households would benefit less than higher-income households from the absence of HIV/AIDS. This suggests that income inequality would be higher during 2002-2025 if HIV/AIDS did not exist. A number of factors can explain this result. First, as mentioned earlier, the increased supply of lower-skilled workers is offset by falling wages, leaving per capita incomes amongst households largely unchanged at the lower end of the distribution. The reverse is true for higher-skilled workers, whose wages rise with faster economic growth. Secondly, unemployment is high among working-age adults living in poorer households. Therefore, reducing adult mortality may increase these households' dependency ratios, causing per capita incomes to fall. This is the case for lower-income households in KZN, where unemployment is particularly high and the growth incidence curve is negative. While removing the effects of HIV/AIDS improves overall household welfare, it is detrimental for lower-income household poverty in KZN, where unemployment is especially severe.

A third reason for the increase in inequality may be better understood by measuring the contribution of the five impact channels to the overall changes in GDP growth rates and poverty rates under the "No AIDS" scenario (see Table 8). The table shows that the effect of HIV/AIDS on labor supply and TFP dominates the economic growth outcomes from the economywide model (i.e., they account for 85 percent of the increase in the GDP growth rate). We have already discussed how increases in labor supply cause declines in lower-skilled workers' wages, thus reducing the income gains due to reduced mortality under the "No AIDS" scenario. Moreover, increased labor productivity and reduced health spending have only small effects on economic growth. Thus, the direct channels linking HIV/AIDS to poorer households are less important than the indirect TFP effects.

Table 8. Contributions of impact channels, 2002-2025

	Growth rate (%)		Poverty rate (%-point)	
	KZN	**RSA**	**KZN**	**RSA**
Total change	1.60	1.42	0.54	-0.99
Labor supply	0.63	0.50	-2.51	-1.36
Labor productivity	0.11	0.08	-0.31	-0.32
Total factor productivity	0.73	0.73	-4.13	-2.64
Private savings/investment	0.13	0.11	-0.84	-0.56
Population growth	0.00	0.00	8.33	3.88

Source: Provincial DCGE model results.
1. Percentage point change in final year poverty rate (i.e., not a percentage change).

The dominance of indirect impact channels is also evident in the poverty decomposition, which shows how the direct channels' contributions to poverty reduction are smaller than that of TFP growth. They are also far smaller than the downward pressure placed on per capita incomes by higher population growth. Thus, TFP drives the overall growth increase and poverty reduction seen in RSA under the "No AIDS" scenario. However, TFP growth does not just benefit households with HIV-infected working adults. Rather, faster economic growth driven by TFP improvements drives up demand for all workers, including those from groups in which HIV prevalence is initially low. Thus, the third explanation for how the removal of HIV/AIDS causes inequality to rise is that TFP benefits all households and workers regardless of their HIV infection status. Higher-income households therefore benefit from faster economic growth despite low infection rates. This finding highlights the importance of taking macroeconomic spillovers into account when assessing the overall impact of HIV/AIDS on growth and poverty.

5. CONCLUSIONS

KwaZulu-Natal, together with the rest of South Africa, suffers from severe unemployment and poverty. Moreover, the province has one of the highest HIV prevalence rates in the world. This paper estimates the impact of HIV/AIDS on economic growth and income poverty in KZN and RSA. Drawing on the findings from a firm-level survey in four of KZN's major economic sectors, we integrate the projections from a demographic model within a regionalized DCGE model. This in turn is linked to a survey-based micro-simulation module in order to estimate poverty and distributional outcomes. This approach extends previous studies by focusing on South Africa's most afflicted region; basing its projections on more reliable estimates of HIV prevalence for workers across occupational groups; and explicitly integrating demographic, economywide, and survey-based models.

The results indicate that HIV/AIDS undermines economic growth in South Africa. It lowers the GDP growth rate by 1.60 and 1.42 percentage points per year in KZN and RSA, respectively. Cumulatively, these losses means that the KZN economy will be 43 percent smaller in 2025 than it would have been in the absence of HIV/AIDS. The rest of the country's economy will be 37 percent smaller. While the detrimental growth-effect is large, the impact of HIV/AIDS on regional poverty headcounts is relatively small, and this inequality would be higher in the absence of HIV/AIDS. The small change in per capita incomes amongst the poor population should be interpreted alongside the estimated 11.8 million projected population decline caused by HIV/AIDS during 2002-2025. Thus, the gains in economic growth in the absence of HIV/AIDS are sufficient to offset the pressure placed on poverty by the survival of a substantially larger population. Moreover, the incentive to mitigate the effects of HIV/AIDS lies not only with poorer households and those with infected members, but also with uninfected and higher-income households that stand to benefit from faster economic growth and rising incomes. These findings reveal that HIV/AIDS places a significant burden on future economic development in KwaZulu-Natal and the rest of the South Africa, and underlines the need for policies and investments to curb the pandemic.

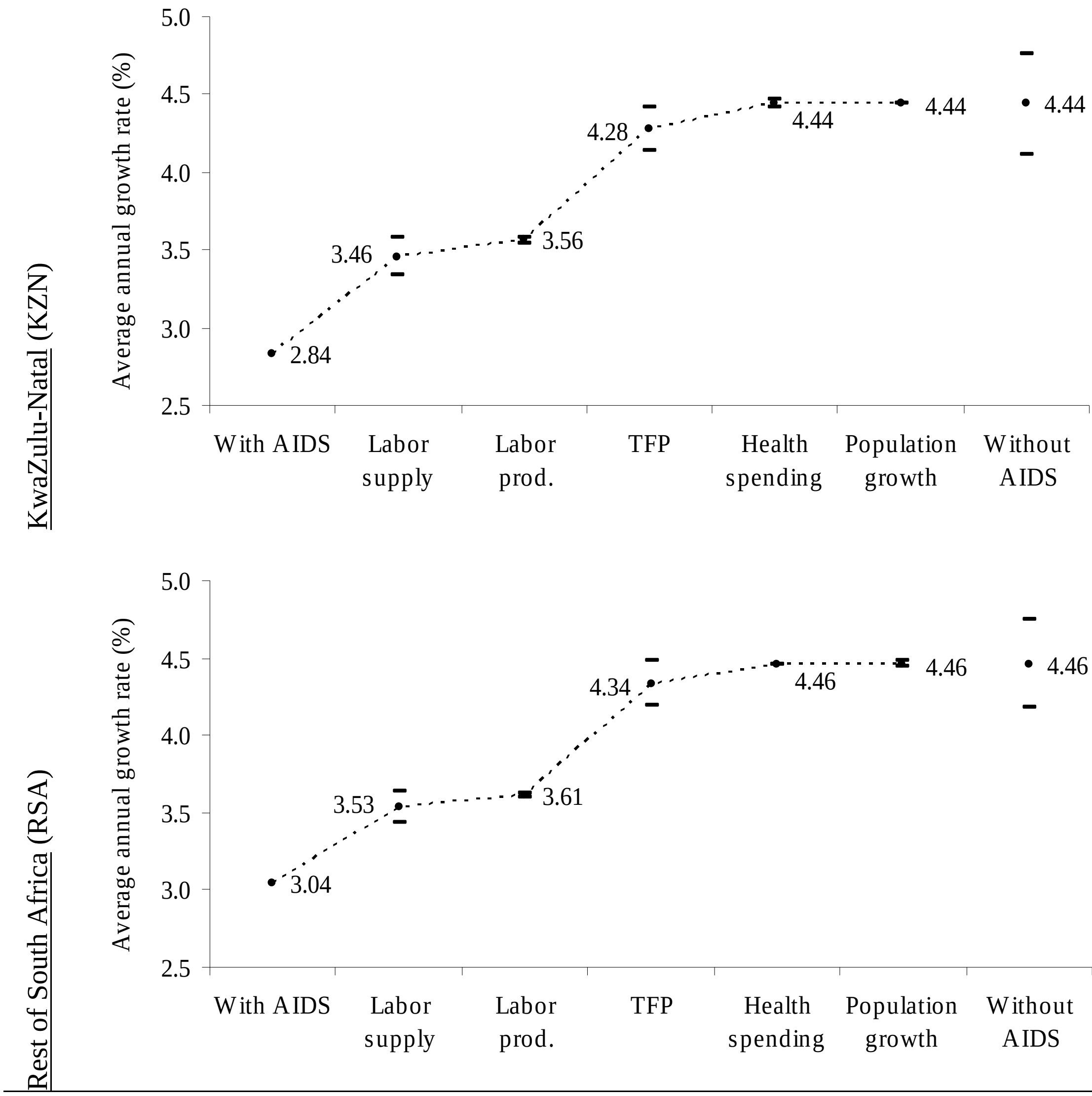
APPENDIX: SENSITIVITY ANALYSIS ON DCGE MODEL RESULTS

Three models are used sequentially in our analysis: ASSA-2003, APM and DCGE. Given the possibility of measurement and model errors at each stage, it is important to consider the sensitivity of our results. For example, the firm-level survey estimated an overall sample HIV prevalence rate with a margin of error of 1.1 percentage points (based on a 95 percent confidence interval). It was necessary to smooth the results across workers and firms in order to arrive at prevalence rates suitable for calibrating the APM. The smoothing methods and confidence intervals around these estimated parameters are described in Matthews et al. (2008). The authors indicate that the confidence intervals are typically narrow, but that some cases have wide margins of error (e.g., the prevalence rate for female African workers in the transport sector). However, these intervals are wide because of the small share of these workers within the sectors' overall workforces. Therefore, the impact on our economywide modeling results is likely to be small.

The dominance of TFP in determining growth and poverty outcomes highlights the need for sensitivity analysis on the DCGE model's results (see Table 7). Accordingly we place a 20 percent confidence interval around the changes in the growth rates for population, labor supply, labor productivity, TFP and health spending (i.e., the five impact channels). Figure A.1 shows how the contribution of each channel varies under these high and low assumptions. For example, in KZN, alteration of the labor supply growth rate has a significant impact on the final GDP growth rate under the "No AIDS" scenario. This is evidenced by the gap between low and high GDP growth rates when the effects of the labor supply channel are isolated. Similarly wide gaps exist for TFP. Combining each channel's upper and lower bounds produces the overall range of growth outcomes under the "No AIDS" scenario. Overall, the sensitivity analysis suggests that HIV/AIDS reduces KZN's GDP growth rate by between 1.28 and 1.93 percent per year. Similarly, the loss of GDP in RSA ranges from 1.14 to 1.71 percent per year. Although these ranges are wide, they assume a persistent accumulation of errors in the same direction for all five channels (i.e., it is assumed that we have either under- or overestimated all channels concurrently).

Figure A.2 shows the sensitivity analysis for poverty outcomes. It is important to note that population changes work in the opposite direction to other channels. The most important channel for determining final-year poverty is the change in the population growth rate, where the upper and lower bounds far exceed those of the other impact channels. While overestimating population growth raises final-year poverty, overestimation of all other channels' growth effects tends to reduce poverty. This explains why the cumulative confidence interval for all other channels combined is relatively narrow. Thus, even if the predicted increase in labor supply under the "No AIDS" scenario is underestimated, this would imply a similar underestimation of population growth, which would dominate and again cause poverty to increase in KZN. The finding that poverty would increase in KZN in the absence of HIV/AIDS is therefore fairly robust to the assumptions on the relative weights of the impact channels. It is, however, sensitive to changes in the definition of the poverty line.

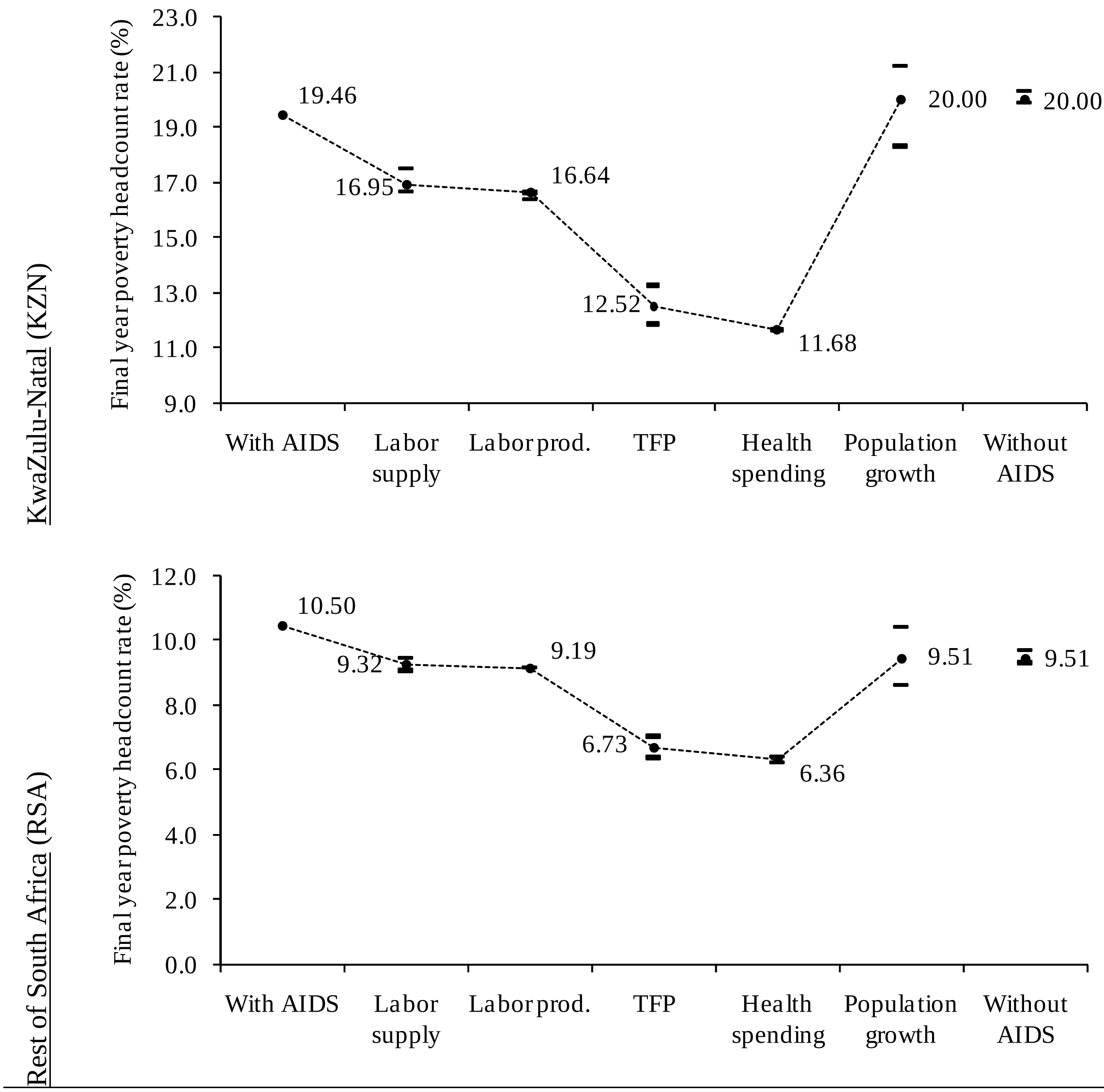
Figure A.1. Channels' impact on average GDP growth, 2002-2025



Source: Provincial DCGE model results.

Note: Outcomes are cumulative (for example, labor productivity includes the outcomes from labor supply). Horizontal bars show upper and lower bounds after assuming a 20 percent confidence interval around the additional growth rate resulting from each impact channel.

Figure A.2. Channels' impact on final year poverty rate, 2025



Source: Provincial DCGE model results.
Note: Outcomes are cumulative (for example, labor productivity includes the outcomes from labor supply). Horizontal bars show upper and lower bounds after assuming a 20 percent confidence interval around the additional growth rate resulting from each impact channel.

REFERENCES

Arndt, C. and J. Lewis. 2001. The HIV/AIDS pandemic in South Africa: Sectoral impacts and unemployment. *Journal of International Development* 13: 427-449.

ASSA. 2005. AIDS and demographic model. Cape Town, South Africa: Actuarial Society of South Africa.

Bhorat, H. and M. Oosthuizen. 2006. Evolution of the labour market: 1995-2000. In *Poverty and policy in post-apartheid South Africa,* Bhorat, H. and R. Kanbur . Pretoria: HSRC Press.

Casale, M. and A. Whiteside. 2006. The impact of HIV/AIDS on poverty, inequality and economic growth. Health Economics and HIV/AIDS Research Division, University of KwaZulu-Natal, South Africa.

Case, A. 2000. Income distribution and expenditure patterns in South Africa. Princeton, NJ: Princeton University. Mimeo.

Fox, M.P., S. Rosen, W.B. MacLeod, M. Wasunna, M., Bii, G. Foglia, and J.L. Simon. 2004. The impact of HIV/AIDS on labour productivity in Kenya. *Tropical Medicine and International Health* 9(3): 318-324.

Freire, S. 2002. *Impact of HIV/AIDS on saving behavior in South Africa.* TEAM, Paris: Sorbonne University

Hoogeveen, J.G. and Özler, B. 2006. Poverty and inequality in post-apartheid South Africa: 1995-2000. In *Poverty and policy in post-apartheid South Africa,* Bhorat, H. and R. Kanbur . Pretoria: HSRC Press.

Matthews, A., G. George, and J. Gow. 2008. *The demographic impact of employment on HIV-AIDS prevalence and incidence: Evidence from KwaZulu-Natal, South Africa*. Health Economics and HIV/AIDS Research Division. KwaZulu-Natal, South Africa: University of KwaZulu-Natal.

Nell, K. 2003. *Long-run exogeneity between saving and investment: Evidence from South Africa.* Working Paper 2-2003. Johannesburg, South Africa: Trade and Industrial Policy Strategies

Quantec. 2007. *Republic of South Africa regional Indicators*. Pretoria, South Africa.

StatsSA. 2001. 2000 Income and expenditure survey. *Statistics.* Pretoria: South Africa.

StatsSA. 2004. Final supply-use tables for South Africa, 2002. *Statistics.* Pretoria: South Africa.

StatsSA. 2005. Labor force survey (September 2004). *Statistics.* Pretoria: South Africa.

Thurlow, J. 2005, *A dynamic computable general equilibrium (CGE) model for South Africa: Extending the static IFPRI model.* Working paper, Trade and Industrial Policy Strategies, Pretoria, South Africa.

Thurlow, J. 2006. Is HIV/AIDS Undermining Botswana's 'Success Story'? IFPRI Discussion Paper, No. 697. Washington, D.C.: International Food Policy Research Institute.

RECENT IFPRI DISCUSSION PAPERS

For earlier discussion papers, please go to www.ifpri.org/pubs/pubs.htm#dp.
All discussion papers can be downloaded free of charge.

863. *The short-run macroeconomic impact of foreign aid to small states: an agnostic time series analysis*. Henrik Hansen and Derek Headey, 2009.

862. *European Union preferential trade agreements with developing countries and their impact on Colombian and Kenyan carnation exports to the United Kingdom.* Guyslain K. Ngeleza and Andrew Muhammad, 2009

861. *The linkages between agriculture and malaria: Issues for policy, research, and capacity strengthening*. Kwadwo Asenso-Okyere, Felix A. Asante, Jifar Tarekegn, andKwaw S. Andam, 2009.

860. *La biotecnología agropecuaria en América Latina: Una visión cuantitativa.* José Falck-Zepeda, César Falcón, Maria José Sampaio-Amstalden, José Luis Solleiro Rebolledo, Eduardo Trigo, and Javier Verástegui, 2009.

859. *Preferential trade agreements between the monetary community of Central Africa and the European Union: Stumbling or building blocks? A general equilibrium approach*. Guyslain K. Ngeleza and Andrew Muhammad, 2009.

858. *Preliminary evidence on internal migration, remittances, and teen schooling in India.* Valerie Mueller and Abusaleh Shariff, 2009.

857. *Productivity convergence in Brazil: The case of grain production.* Eduardo Magalhaes and Xinshen Diao, 2009.

856. *Dynamics of structural transformation: An empirical characterization in the case of China, Malaysia, and Ghana*. Thaddee Badibanga, Xinshen Diao, Terry Roe, and Agapi Somwaru, 2009.

855. *Do institutions limit clientelism? A study of the district assemblies common fund in Ghana*. Afua Branoah Banful, 2009.

854. *The evolution of Chinese entrepreneurial firms: Township-village enterprises revisited*. Chenggang Xu and Xiaobo Zhang, 2009.

853. *Evaluating the impact of land tenure and titling on access to credit in Uganda*. Carly K. Petracco and John Pender, 2009.

852. *Participation by Men and Women in Off-Farm Activities: An Empirical Analysis in Rural Northern Ghana*. Nancy McCarthy and Yan Sun, 2009.

851. *Measuring agricultural innovation system properties and performance: Illustrations from Ethiopia and Vietnam.* David J. Spielman and Dawit Kelemework, 2009.

850. *Are returns to mothers' human capital realized in the next generation?: The impact of mothers' intellectual human capital and long-run nutritional status on children's human capital in Guatemala*. Jere R. Behrman, Alexis Murphy, Agnes R. Quisumbing, and Kathryn Yount, 2009.

849. *Understanding Farmers' Perceptions and Adaptations to Climate Change and Variability: The Case of the Limpopo Basin, South Africa*. Glwadys Aymone Gbetibouo, 2009.

848. *Agglomeration, migration, and regional growth: A CGE analysis for Uganda*. Paul Dorosh and James Thurlow, 2009.

847. *Biosafety decisions and perceived commercial risks: The role of GM-free private standards.* Guillaume Gruère and Debdatta Sengupta, 2009.

846. *Impact of soaring food price in Ethiopia: does location matter?* John M. Ulimwenju, Sindu Workneh, and Zelekawork Paulos, 2009.

845. A*ggregate effects of imperfect tax enforcement*. Miguel Robles, 2009.

844. *Agricultural strategy development in West Africa: The false promise of participation?* Danielle Resnick and Regina Birner, 2008.

843. *Climate variability and maize yield in South Africa: Results from GME and MELE methods*. Wisdom Akpalu, Rashid M. Hassan, and Claudia Ringler, 2008.

842. *Local impacts of a global crisis: Food price transmission and poverty impacts in Ghana*. Godsway Cudjoe, Clemens Breisinger, and Xinshen Diao, 2008.

841. *Technology transfer, policies, and the role of the private sector in the global poultry revolution*. Clare A. Narrod, Carl E. Pray, and Marites Tiongco, 2008.

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

www.ifpri.org

IFPRI HEADQUARTERS

2033 K Street, NW
Washington, DC 20006-1002 USA
Tel.: +1-202-862-5600
Fax: +1-202-467-4439
Email: ifpri@cgiar.org

IFPRI ADDIS ABABA

P. O. Box 5689
Addis Ababa, Ethiopia
Tel.: +251 11 6463215
Fax: +251 11 6462927
Email: ifpri-addisababa@cgiar.org

IFPRI NEW DELHI

CG Block, NASC Complex, PUSA
New Delhi 110-012 India
Tel.: 91 11 2584-6565
Fax: 91 11 2584-8008 / 2584-6572
Email: ifpri-newdelhi@cgiar.org