LIVES SAVED BY EXPANDING HIV TREATMENT AVAILABILITY IN RESOURCE-LIMITED SETTINGS: THE EXAMPLE OF HAITI

KIMMEL ET AL.

SUPPLEMENTAL DIGITAL CONTENT
This supplemental content provides further details on the methods and analysis results. In the text that follows, we present additional information on the model structure, initial probability distribution, and sensitivity analysis results.

**SUPPLEMENTAL METHODS**

**Model structure and implementation**

We used country-specific patient-level data on untreated and treated HIV disease progression,\(^1-^7\) as well as country-level reports on the number on ART annually in Haiti\(^8\) to develop a multi-cohort mathematical model. The model is structured as a Markov model, defined broadly by a set of mutually exclusive and collectively exhaustive health states, by ongoing risks over time, and by a property specifying that events occurring in a subsequent model cycle depend only on the current cycle and not on previous ones.\(^9\) Movement between health states occurs probabilistically, with transitions occurring as a series of possible events within a specified time frame.\(^9,^{10}\)

In the current model, we define 12 main health states (Figure S1). These health states are differentiated by disease progression (i.e., CD4 count >350 cells/µL or asymptomatic HIV disease, CD4 count 200–350 cells/µL or Intermediate HIV disease with or without symptoms, and CD4 count <200 cells/µL or AIDS) and engagement with clinical care (not in care, in care but off ART, on ART, loss from treatment or care, death). Up to two sequential ART regimens are available, and residence in ART-related health states is based on disease stage at the time of ART initiation. The model applies transition probabilities to govern the fraction of each cohort moving among the health stages. Individuals may die of HIV/AIDS- or non-HIV/AIDS-related causes; mortality risk varies based on both disease stage and clinical engagement. The model also accounts for the higher mortality risk in the first year of treatment among individuals initiating ART late in the disease course (i.e., CD4 count <200 cells/µL).\(^11\) Given the relatively short analytic time horizon of 10 years, we assume the probability of death is constant. Death is represented by a single absorbing health state. The model is implemented in spreadsheet format in Microsoft Excel 2010 (Redmond, Washington, USA). This software platform has a straightforward, intuitive user interface that was used to promote transparency and interpretive accessibility of both the model and results.\(^12,^{13}\)

**Initial health state distribution**

Model inputs for the initial health state distribution, or the prevalent HIV-infected cohort (2004), came from country-level reports, demographic and health surveys, and the model verification process.\(^14\) The model verification process relied on patient-level data from Haiti for treated and untreated disease progression (used in model projections for 2005 – 2020), the number receiving ART in Haiti (2004 – 2009), UNAIDS assessments of the number of HIV-infected individuals living in Haiti (2004 only), and the 2006 Demographic and Health Surveys examining the fraction of the HIV-infected population unaware of their serostatus (applied to 2004 modeled cohort).\(^1-^8,^{15}\) The initial probability distribution across the non-absorbing health states is shown in Table S1. In the prevalent cohort (i.e., 2004), the number of individuals in each health state can be calculated by taking the product of the initial probability for each health state.
state and the total estimated number of HIV-infected individuals living in Haiti in 2004 (estimated 110,000). In the prevalent cohort, we also assume no individuals receive 2^nd-line ART.

SUPPLEMENTAL RESULTS

Sensitivity Analyses

Selected supplementary sensitivity analysis results are shown in Tables S2 – S4 and in Figure S2.
SUPPLEMENTAL REFERENCES


Table S1. Initial Probability Distribution Across Health States

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Source(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimates used in model verification process for initial health stage distribution</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total HIV-infected population (number)</td>
<td>110,000</td>
<td>UNAIDS(^8)</td>
</tr>
<tr>
<td>Number on ART (number)</td>
<td>3,000</td>
<td>UNAIDS(^8)</td>
</tr>
<tr>
<td>Fraction unaware of HIV serostatus</td>
<td>0.750</td>
<td>DHS 2006(^{15})</td>
</tr>
</tbody>
</table>

Initial health stage distribution (prevalent cohort, 2004)

Initial distribution of asymptomatic health states, by degree of clinical engagement*

| Not in care                               | 0.339 | UNAIDS\(^8\), DHS 2006\(^{15}\), Model verification† |
| In care and off ART                       | 0.078 | UNAIDS\(^8\), DHS 2006\(^{15}\), Model verification† |
| Lost from care                            | 0.035 | UNAIDS\(^8\), DHS 2006\(^{15}\), Model verification† |

Initial distribution of intermediate HIV health states, by degree of clinical engagement*

| Not in care                               | 0.227 | UNAIDS\(^8\), DHS 2006\(^{15}\), Model verification† |
| In care and off ART                       | 0.058 | UNAIDS\(^8\), DHS 2006\(^{15}\), Model verification† |
| On 1st-line ART                           | 0.005 | UNAIDS\(^8\), Model verification†                   |
| Lost from treatment or care               | 0.013 | UNAIDS\(^8\), DHS 2006\(^{15}\), Model verification† |

Initial distribution of AIDS health states, by degree of clinical engagement*

| Not in care                               | 0.184 | UNAIDS\(^8\), DHS 2006\(^{15}\), Model verification† |
| In care and off ART                       | 0.036 | UNAIDS\(^8\), DHS 2006\(^{15}\), Model verification† |
| On 1st-line ART                           | 0.022 | UNAIDS\(^8\), Model verification†                   |
| Lost from treatment or care               | 0.002 | UNAIDS\(^8\), DHS 2006\(^{15}\), Model verification† |

Abbreviations: ART = antiretroviral therapy; Asymptomatic = HIV-infected individuals with CD4 count >350 cells/µL; Intermediate = HIV-infected individuals with CD4 count 200–350 cells/µL; AIDS = HIV-infected individuals with CD4 count <200 cells/µL; Lost = loss from HIV treatment or care; mo = months.

* The number of individuals in each health state in the prevalent cohort (i.e., the cohort entering the model in 2004) can be calculated by multiplying the initial probability by the total HIV-infected population estimated by UNAIDS.\(^8\) We assume no individuals have initiated second-line ART. The sum of the probabilities across all health states does not equal 1 due to rounding.

† The model verification process was used to confirm that model projections correspond with historical data on ART scale-up in Haiti. The process involves systematically varying multiple, uncertain model input parameters and identifying the input values resulting in model outcomes that best approximate empirical data.\(^{16}\)
<table>
<thead>
<tr>
<th>Scenario*</th>
<th>Number in Care, Off ART</th>
<th>Number on ART</th>
<th>Cumulative Deaths, Beginning in 2010</th>
<th>ART Coverage,† CD4 &lt;350 cells/µL</th>
</tr>
</thead>
<tbody>
<tr>
<td>**Linkage to Care</td>
<td>Asymptomatic**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Lower Bound = 0.058</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No new ART</td>
<td>19,600 19,100</td>
<td>22,000 17,700</td>
<td>55,600 105,100</td>
<td>0.327 0.287</td>
</tr>
<tr>
<td>Fixed Capacity</td>
<td>16,700 16,000</td>
<td>27,300 27,000</td>
<td>54,300 100,400</td>
<td>0.395 0.404</td>
</tr>
<tr>
<td>Current rates</td>
<td>11,600 11,200</td>
<td>37,400 43,200</td>
<td>50,200 89,900</td>
<td>0.511 0.559</td>
</tr>
<tr>
<td>Limited expansion</td>
<td>9,800 9,600</td>
<td>40,900 48,800</td>
<td>49,200 86,900</td>
<td>0.551 0.608</td>
</tr>
<tr>
<td>Full expansion</td>
<td>9,400 9,100</td>
<td>42,100 50,600</td>
<td>48,500 85,600</td>
<td>0.562 0.620</td>
</tr>
<tr>
<td><strong>Upper bound = 0.089</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No new ART</td>
<td>20,900 19,900</td>
<td>22,000 17,700</td>
<td>55,600 104,700</td>
<td>0.328 0.288</td>
</tr>
<tr>
<td>Fixed Capacity</td>
<td>17,800 16,800</td>
<td>27,500 27,300</td>
<td>54,300 99,900</td>
<td>0.399 0.408</td>
</tr>
<tr>
<td>Current rates</td>
<td>12,700 12,100</td>
<td>37,600 43,400</td>
<td>50,100 89,500</td>
<td>0.514 0.561</td>
</tr>
<tr>
<td>Limited expansion</td>
<td>10,900 10,400</td>
<td>41,100 49,000</td>
<td>49,200 86,400</td>
<td>0.556 0.610</td>
</tr>
<tr>
<td>Full expansion</td>
<td>10,500 10,000</td>
<td>42,300 50,700</td>
<td>48,500 85,200</td>
<td>0.567 0.621</td>
</tr>
<tr>
<td>**Linkage to Care</td>
<td>Intermediate HIV**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Lower bound = 0.078</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No new ART</td>
<td>20,000 19,200</td>
<td>22,000 17,700</td>
<td>55,700 105,000</td>
<td>0.328 0.288</td>
</tr>
<tr>
<td>Fixed Capacity</td>
<td>17,000 16,200</td>
<td>27,300 27,000</td>
<td>54,300 100,300</td>
<td>0.396 0.405</td>
</tr>
<tr>
<td>Current rates</td>
<td>12,000 11,500</td>
<td>37,300 43,000</td>
<td>50,200 89,900</td>
<td>0.510 0.558</td>
</tr>
<tr>
<td>Limited expansion</td>
<td>10,300 9,900</td>
<td>40,600 48,400</td>
<td>49,300 87,000</td>
<td>0.550 0.605</td>
</tr>
<tr>
<td>Full expansion</td>
<td>9,800 9,500</td>
<td>41,900 50,100</td>
<td>48,600 85,700</td>
<td>0.561 0.617</td>
</tr>
<tr>
<td><strong>Upper bound = 0.118</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No new ART</td>
<td>20,600 19,800</td>
<td>22,000 17,700</td>
<td>55,600 104,800</td>
<td>0.328 0.287</td>
</tr>
<tr>
<td>Fixed Capacity</td>
<td>17,500 16,600</td>
<td>27,500 27,300</td>
<td>54,200 100,000</td>
<td>0.398 0.408</td>
</tr>
<tr>
<td>Current rates</td>
<td>12,300 11,800</td>
<td>37,700 43,600</td>
<td>50,100 89,500</td>
<td>0.515 0.562</td>
</tr>
<tr>
<td>Limited expansion</td>
<td>10,500 10,100</td>
<td>41,300 49,400</td>
<td>49,100 86,300</td>
<td>0.557 0.613</td>
</tr>
<tr>
<td>Full expansion</td>
<td>10,000 9,700</td>
<td>42,500 51,100</td>
<td>48,400 85,100</td>
<td>0.568 0.624</td>
</tr>
<tr>
<td>**Linkage to Care</td>
<td>AIDS**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Lower bound = 0.370</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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<td>22,000 17,700</td>
<td>55,600 104,900</td>
<td>0.328 0.287</td>
</tr>
<tr>
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<td>27,400 27,200</td>
<td>54,300 100,200</td>
<td>0.397 0.407</td>
</tr>
<tr>
<td>Current rates</td>
<td>12,000 11,500</td>
<td>37,200 42,800</td>
<td>50,300 90,100</td>
<td>0.510 0.556</td>
</tr>
<tr>
<td>Limited expansion</td>
<td>10,200 9,900</td>
<td>40,700 48,400</td>
<td>49,400 87,000</td>
<td>0.551 0.606</td>
</tr>
<tr>
<td>Full expansion</td>
<td>9,800 9,400</td>
<td>41,800 50,100</td>
<td>48,700 85,800</td>
<td>0.561 0.617</td>
</tr>
<tr>
<td><strong>Upper bound = 0.561</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No new ART</td>
<td>20,700 19,900</td>
<td>22,000 17,700</td>
<td>55,600 104,900</td>
<td>0.328 0.287</td>
</tr>
<tr>
<td>Fixed Capacity</td>
<td>17,500 16,600</td>
<td>27,400 27,200</td>
<td>54,300 100,100</td>
<td>0.397 0.406</td>
</tr>
<tr>
<td>Current rates</td>
<td>12,300 11,800</td>
<td>37,700 43,600</td>
<td>50,000 89,500</td>
<td>0.514 0.562</td>
</tr>
<tr>
<td>Limited expansion</td>
<td>10,500 10,100</td>
<td>41,200 49,200</td>
<td>49,100 86,400</td>
<td>0.556 0.611</td>
</tr>
<tr>
<td>Full expansion</td>
<td>10,000 9,700</td>
<td>42,400 51,000</td>
<td>48,400 85,100</td>
<td>0.567 0.623</td>
</tr>
</tbody>
</table>

Abbreviations: ART = antiretroviral therapy; mo = months.
* Sources for each scenario’s lower bound and upper bounds are indicated in Table 2 of the main text.
† ART coverage is defined as the fraction of those eligible for ART who actually receive it. Reported estimates assume ART eligibility at CD4 count <350 cells/µL.
Table S3. Selected Univariate Sensitivity Analysis Results: Pre-ART Loss from Care

<table>
<thead>
<tr>
<th>Scenario*</th>
<th>Number in Care, Off ART</th>
<th>Number on ART</th>
<th>Cumulative Deaths, Beginning in 2010</th>
<th>ART Coverage,† CD4 &lt;350 cells/µL</th>
</tr>
</thead>
<tbody>
<tr>
<td>**Pre-ART Loss from Care</td>
<td>Asymptomatic**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower bound = 0.097</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No new ART</td>
<td>23,200</td>
<td>23,100</td>
<td>22,000</td>
<td>17,700</td>
</tr>
<tr>
<td>Fixed Capacity</td>
<td>19,900</td>
<td>19,400</td>
<td>27,400</td>
<td>27,700</td>
</tr>
<tr>
<td>Current rates</td>
<td>14,500</td>
<td>14,200</td>
<td>37,900</td>
<td>44,800</td>
</tr>
<tr>
<td>Limited expansion</td>
<td>12,600</td>
<td>12,400</td>
<td>41,600</td>
<td>50,800</td>
</tr>
<tr>
<td>Full expansion</td>
<td>12,200</td>
<td>11,900</td>
<td>42,800</td>
<td>52,600</td>
</tr>
<tr>
<td>Upper bound = 0.740</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No new ART</td>
<td>17,900</td>
<td>17,000</td>
<td>22,000</td>
<td>17,700</td>
</tr>
<tr>
<td>Fixed Capacity</td>
<td>14,900</td>
<td>14,100</td>
<td>27,500</td>
<td>27,100</td>
</tr>
<tr>
<td>Current rates</td>
<td>10,200</td>
<td>9,800</td>
<td>36,900</td>
<td>42,000</td>
</tr>
<tr>
<td>Limited expansion</td>
<td>8,600</td>
<td>8,300</td>
<td>40,300</td>
<td>47,200</td>
</tr>
<tr>
<td>Full expansion</td>
<td>8,200</td>
<td>7,900</td>
<td>41,400</td>
<td>48,900</td>
</tr>
<tr>
<td>**Pre-ART Loss from Care</td>
<td>Intermediate HIV**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower bound = 0.404</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No new ART</td>
<td>24,000</td>
<td>24,000</td>
<td>22,000</td>
<td>17,700</td>
</tr>
<tr>
<td>Fixed Capacity</td>
<td>20,300</td>
<td>19,600</td>
<td>27,400</td>
<td>27,700</td>
</tr>
<tr>
<td>Current rates</td>
<td>13,800</td>
<td>13,200</td>
<td>38,900</td>
<td>46,300</td>
</tr>
<tr>
<td>Limited expansion</td>
<td>11,200</td>
<td>10,800</td>
<td>42,600</td>
<td>52,000</td>
</tr>
<tr>
<td>Full expansion</td>
<td>10,000</td>
<td>9,600</td>
<td>45,000</td>
<td>55,500</td>
</tr>
<tr>
<td>Upper bound = 0.740</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No new ART</td>
<td>17,100</td>
<td>16,200</td>
<td>22,000</td>
<td>17,700</td>
</tr>
<tr>
<td>Fixed Capacity</td>
<td>14,600</td>
<td>13,800</td>
<td>27,400</td>
<td>26,800</td>
</tr>
<tr>
<td>Current rates</td>
<td>10,700</td>
<td>10,300</td>
<td>36,000</td>
<td>40,400</td>
</tr>
<tr>
<td>Limited expansion</td>
<td>10,400</td>
<td>10,000</td>
<td>36,800</td>
<td>41,600</td>
</tr>
<tr>
<td>Full expansion</td>
<td>9,900</td>
<td>9,600</td>
<td>38,000</td>
<td>43,300</td>
</tr>
<tr>
<td>**Pre-ART Loss from Care</td>
<td>AIDS**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower bound = 0.005</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No new ART</td>
<td>21,500</td>
<td>20,900</td>
<td>22,000</td>
<td>17,700</td>
</tr>
<tr>
<td>Fixed Capacity</td>
<td>18,300</td>
<td>17,400</td>
<td>27,500</td>
<td>27,500</td>
</tr>
<tr>
<td>Current rates</td>
<td>12,500</td>
<td>11,900</td>
<td>38,000</td>
<td>44,200</td>
</tr>
<tr>
<td>Limited expansion</td>
<td>10,700</td>
<td>10,300</td>
<td>41,500</td>
<td>49,700</td>
</tr>
<tr>
<td>Full expansion</td>
<td>10,000</td>
<td>9,600</td>
<td>43,100</td>
<td>52,100</td>
</tr>
<tr>
<td>Upper bound = 0.155</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No new ART</td>
<td>18,600</td>
<td>17,800</td>
<td>22,000</td>
<td>17,700</td>
</tr>
<tr>
<td>Fixed Capacity</td>
<td>15,800</td>
<td>15,000</td>
<td>27,400</td>
<td>27,100</td>
</tr>
<tr>
<td>Current rates</td>
<td>11,700</td>
<td>11,300</td>
<td>36,700</td>
<td>42,000</td>
</tr>
<tr>
<td>Limited expansion</td>
<td>10,000</td>
<td>9,700</td>
<td>40,300</td>
<td>47,700</td>
</tr>
<tr>
<td>Full expansion</td>
<td>10,000</td>
<td>9,600</td>
<td>40,500</td>
<td>48,000</td>
</tr>
</tbody>
</table>

Abbreviations: ART = antiretroviral therapy.
* Sources for each scenario’s lower bound and upper bounds are indicated in Table 2 of the main text.
† ART coverage is defined as the fraction of those eligible for ART who actually receive it. Reported estimates assume ART eligibility at CD4 count <350 cells/µL.
### Table S4. Selected Univariate Sensitivity Analysis Results: Number Newly Infected Annually

<table>
<thead>
<tr>
<th>Scenario*</th>
<th>Number in Care, Off ART</th>
<th>Number on ART</th>
<th>Cumulative Deaths, Beginning in 2010</th>
<th>ART Coverage,† CD4 &lt;350 cells/µL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Constant Annual HIV Incidence</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Lower Bound = 6,500 annually</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No new ART</td>
<td>18,200</td>
<td>15,400</td>
<td>22,000</td>
<td>17,700</td>
</tr>
<tr>
<td>Fixed Capacity</td>
<td>15,200</td>
<td>12,700</td>
<td>27,400</td>
<td>26,500</td>
</tr>
<tr>
<td>Current rates</td>
<td>10,400</td>
<td>9,000</td>
<td>37,000</td>
<td>40,600</td>
</tr>
<tr>
<td>Limited expansion</td>
<td>8,900</td>
<td>7,700</td>
<td>40,400</td>
<td>45,400</td>
</tr>
<tr>
<td>Full expansion</td>
<td>8,400</td>
<td>7,400</td>
<td>41,500</td>
<td>47,000</td>
</tr>
<tr>
<td><strong>Upper bound = 11,000 annually</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No new ART</td>
<td>22,800</td>
<td>24,400</td>
<td>22,000</td>
<td>17,700</td>
</tr>
<tr>
<td>Fixed Capacity</td>
<td>19,700</td>
<td>20,700</td>
<td>27,300</td>
<td>27,900</td>
</tr>
<tr>
<td>Current rates</td>
<td>14,200</td>
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Abbreviations: ART = antiretroviral therapy; † = given; mo = months.

* Sources for each scenario’s lower bound and upper bounds are indicated in Table 2 of the main text.
† ART coverage is defined as the fraction of those eligible for ART who actually receive it. Reported estimates assume ART eligibility at CD4 count <350 cells/µL.
Figure S1. Detailed model schematic. The model contains 12 main health states, which are defined by mutually exclusive stages of disease progression (Asymptomatic or CD4 count >350 cells/µL, Intermediate HIV or CD4 count 200 – 350 cells/µL, and AIDS or CD4 count <200 cells/µL) and engagement with clinical care (Not in Care, In Care and off ART, on ART, Lost to Follow-up, and Dead). During each model cycle, a fraction of each cohort moves among the health states, with arrows representing movement in the form of transition probabilities, from one health state to another. Both 1\textsuperscript{st}- and 2\textsuperscript{nd}-line ART are available, and the model accounts for a higher mortality risk in the first year of treatment among individuals initiating ART late in the disease course (i.e., CD4 count <200 cells/µL).\textsuperscript{11} The probability of remaining in a health state at a new model cycle is not depicted. Death can occur from AIDS- or non-AIDS-related causes. In the multi-cohort model, the prevalent cohort is distributed across the health states; successive cohorts of newly HIV-infected individuals enter the model as asymptomatic and not in care. Abbreviations: Asympt = Asymptomatic; ART = antiretroviral therapy; ART = antiretroviral therapy; Lost = loss from treatment or care.
Figure S2. Sensitivity analysis: percent difference of the No New ART and Full Expansion scenarios compared to the base case for two health outcomes. Percent difference in health outcomes is shown on the horizontal axis; variation shown on the horizontal axis results from changes in select individual-level model parameters, which are listed on the vertical axis. The lower (upper) bound of the range represents the percent difference in outcomes due to variation of a model parameter for the No New ART (Full Expansion) scenario compared to the base case. Panel A shows the percent difference with regard to cumulative deaths over ten years. Panel B shows the percent difference with regard to ART coverage. ART: antiretroviral therapy; VCT: voluntary counseling and testing.