NEPAD's Integrated Approach for African Development: The Big Push to 2063

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Lead Author:
Jonathan D. Moyer

Contributing Authors:
Jessica Rettig
David K. Bohl
Barry B. Hughes

Analytic Support:
Alison Burt, Drew Bowlsby, Michael Dabbs, Ara Go, Steve Hedden, Katherine Hill, Mohammod T. Irfan, John McPhee, Carey Neill, Pete Oesterling, Mickey Rafa, Dale S. Rothman, José R. Solórzano, Sara Turner

pardee.du.edu

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Executive Summary

In 1963, the founders of the Organization for African Unity foresaw a brighter future for Africa, one that would be achieved in part through unity and solidarity across the continent. Now, 50 years later, African leaders, working together within the African Union (AU), have called for a renewed commitment to development and prosperity for all Africans. Through *Agenda 2063*, Africa has the opportunity to take the lessons of the past and apply them to the next 50 years, working toward a future even more promising than the original OAU founders may have imagined.

African governments today seek to improve development across an ever-expanding set of issue areas. Even as the United Nations moves beyond the Millennium Development Goals toward a post-2015 framework, a wide range of African actors—civil society and the private sector, for example—is pressing for enhanced development policy. Governments are simultaneously expected to increase agricultural production, strengthen infrastructure, enhance health and education, improve governance and security, make society more equitable for gender and income groups, effectively manage natural resources, diversify economic production, and protect the environment. This panoply of development issues makes it challenging to evaluate among strategic policy options. The complexity and density of the policy-making space in Africa calls for a structured and integrated approach to decision making.

Given its relative objectivity, integrated policy analysis encourages stakeholders on all sides to develop evidence-based, shared expectations about African development

Integrated policy analysis is the process of understanding development trends, setting aggressive but reasonable targets, and producing evidence-based assessments for the continent, regions, and individual countries that can be used for monitoring and evaluation. This process begins by analyzing issue areas both internally and as they interact with each other. From there, historical development patterns can be explored and projected into the future. Given its relative objectivity, integrated policy analysis encourages stakeholders on all sides to develop evidence-based, shared expectations about African development.

Integrated policy analysis is the process of evaluating development trends, setting aggressive but reasonable targets, and producing evidence-based assessments for the continent, its regions, and individual countries.

Moving beyond the current path of development, the New Partnership for African Development (NEPAD) programme's integrated policy analysis is concerned with unpacking the kinds of development choices Africa can make today and the expected influence that such decisions might have across all key systems. This kind of analysis lies at the core of the NEPAD agency, which itself is integrated across issue areas, horizontally across the countries of the AU, and vertically through Regional Economic Commissions and the African Union Commission. This report will demonstrate how NEPAD can use its analytical framework—across issues, countries, and time—to develop a comprehensive vision for the African continent that is robust, desirable, and sustainable.

After introducing the methods in some depth, the report identifies several key development trends in the **Current Path** of African development. These trends help build reasonable expectations about the future. A sample includes:

- Food production and imports are both increasing, providing more calories per person in Africa.
- New technologies offer an increasingly greater possibility for energy production within the continent.
- Access to basic infrastructure is improving and expands opportunities for greater intranational and intra-African trade.
- Educational attainment has improved across the board; in 50 years, it is reasonable to expect that tertiary enrollment rates will more than triple.
- Fatalities due to communicable disease—such as AIDS or malaria—are dropping and projected to decline by half by the early 2040s, even as populations grow.

The trends emerging on the African continent are largely positive, but with aggressive broad-scale policy support, an even more prosperous renewal is possible. By simulating such support both within and across major development systems, the findings here suggest that an **Integrated Push** for progress is preferable to a piecemeal strategy that addresses one issue at a time or inflexibly prioritizes one over the other.

This report compares seven potential paths for development. For each path, this approach maps out how such interventions would affect Africa's development systems at the continental level, particularly on three measures: poverty, HDI, and GDP (see side-bar for more information). These three measures capture a wide range of development across issue areas including that of Africa's poorest people to its most prosperous institutions. Note that the same approach could be deployed through Agenda 2063 to forecast development at both a regional and national level, taking into account each country's unique circumstances and distinct strategic positions.

Measuring Development

Extreme poverty: The number of people living on less than $1.25 per day. Reducing this variable helps improve the lives of the poorest Africans.

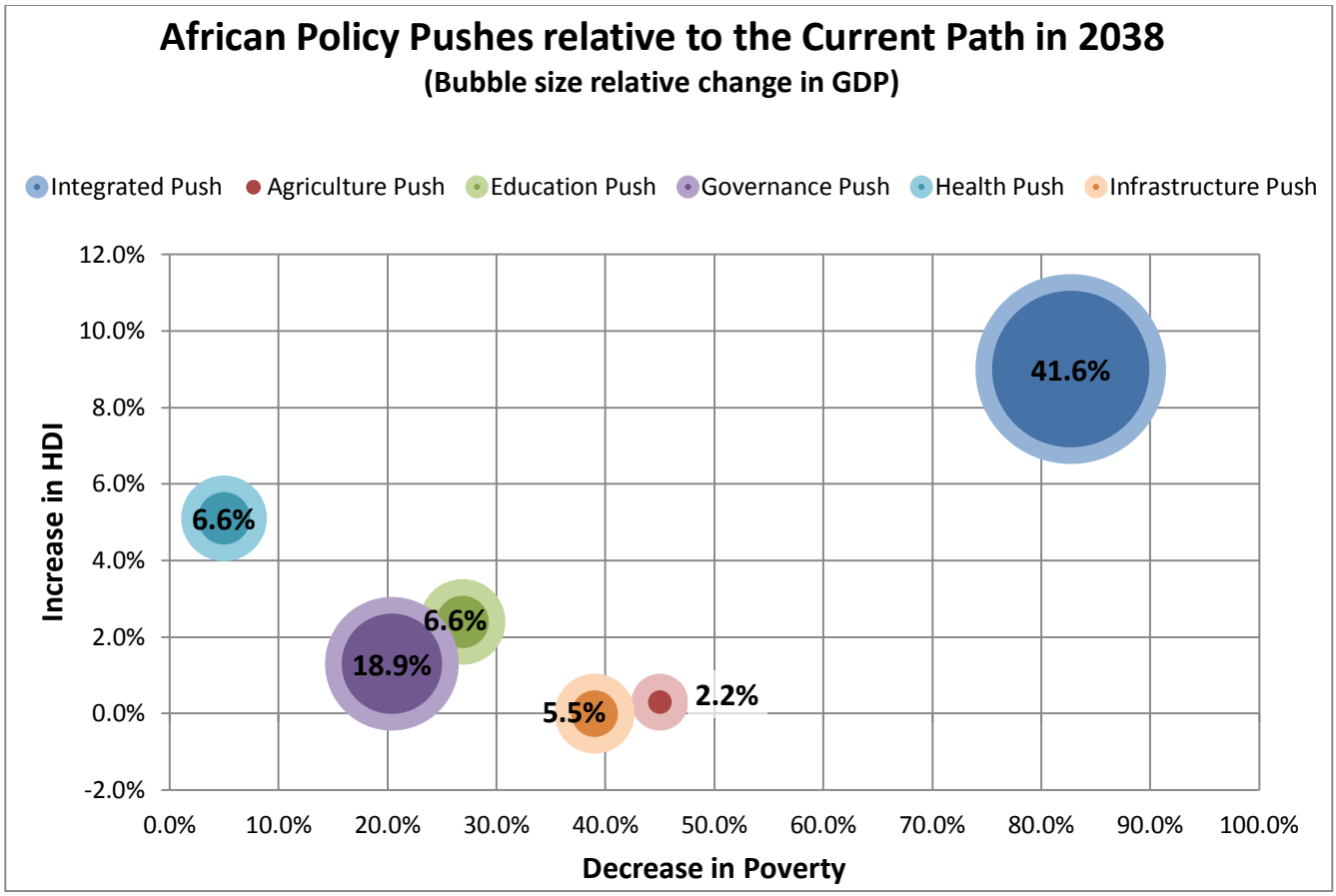
Human Development Index (HDI): The 2010 revision includes the logged measure of per capita production, expected years of education, average years of education, and life expectancy. Increasing this measure represents broad-based improvements in societal development.

Gross Domestic Production: The total amount of goods and services produced in a country, region, or continent. Increases in this variable represent the overall size of the African economy. It is also a proximate variable for the amount of resources that can be spent on development policy.

The analysis begins with Africa's **Current Path**, a forecast that is a continuation of today's policy choices and technological advances. While partially optimistic, it assumes no major changes to existing dynamics and serves as a point of comparison with the six alternatives. By contrast, the next five potential paths incorporate aggressive but reasonable improvements in only one major policy area at a time. The policy areas chosen for this report—agriculture, health, education, infrastructure, and governance—are each vital elements of African development.

Each of these alternative "Push" scenarios focuses on specific strategic choices available to policy makers. Any policy choice can, of course, limit the resources available for other developmental priorities. Yet many choices and policies are also very complementary and can take advantage of new opportunities and resources that they collectively generate. Thus despite the measurable benefits that each issue-oriented path might provide, the seventh and **Integrated Push**—one that combines policy support for all five areas at once—holds the most promise for Africa in the long term. The integration of all systems together, across countries and across time, leads to enhanced overall outcomes: reducing poverty and improving human development, all while encouraging greater economic prosperity for the continent as a whole.

The figure below demonstrates initial findings for development across issue areas at the continental level, halfway from now to 2063. The forecasted values represent the improvements made under each **Push** relative to the **Current Path** across the three key indicators listed above. Using such forecasts, the isolated policy pushes can be compared with more integrated policymaking. While the **Current Path** is largely positive, an **Integrated Push** across policy areas could deliver additional improvements in HDI by roughly 9 percent, a reduction of extreme poverty by over 80 percent, and an increase in overall production of more than 40 percent—in just 25 years.



The following report demonstrates integrated policy analysis at the continental level. Thus, the results should not be applied to the national level or even at the Regional Economic Community level. The

continent is very diverse, and any analysis exploring strategic choices should only inform decision-making after a fully consultative process involving all relevant stakeholders. However, when done properly, this kind of assessment can act as a backbone for continental-, regional-, or country-level development targeting or empirically backed monitoring and evaluation. By adopting an integrated approach to thinking about the future, the NEPAD agency, as a technical body of the AU, can accelerate the continent's enhancement of human development over the next five decades.

Preface

This report is intended to demonstrate the long-term analytical capabilities of the New Partnership for Africa's Development (NEPAD) and its strategic programmes. The integrated policy analysis employed here draws upon the International Futures (IFs) modelling system, a one-of-a-kind forecasting tool that has helped governments and international organizations around the world explore historical trends and better understand the interactions among major development systems. Through such analysis, IFs offers policymakers a way to think more reasonably about the future.

IFs formally represents development across 11 major global systems: demographics, economics, health, education, energy, agriculture, infrastructure, environment, governance, technology, and international politics. It integrates these systems across 186 of the most populous countries in the world.

Every approach to creating development policy has strengths and weaknesses. While the IFs system is state-of-the-art, it does not cover all issues with the same focus and depth. This is a result of data restrictions, modelling constraints, and the difficulties in understanding complex human and social systems. Because of these challenges, modelers of the IFs system often delineate between forecasting and prediction. Forecasts are contingent, plausible statements about the likely unfolding of a trend. Prediction, by contrast, is a much more concrete statement about what will or will not happen at some point in the future. While some of the numbers and figures below could be interpreted as predictions, they should be understood solely as forecasts.

Note that nearly all comparisons in this document were made relative to the Current Path: a forecast which represents the unfolding of key development systems if Africa pursues today's existing policies, and if no major changes occur. This should be understood as a dynamic baseline that extends historical trends according to the current understanding of the relationships among major systems. All of these estimates—which include the Current Path and other policy-driven alternatives—are not intended for use as targets. Rather, they help us to better conceptualize the relative trajectories of the continent.

Also keep in mind that most of the forecasts in this report extend out 50 years to the final year of the African Union's Agenda 2063. In some cases, the forecasts consider outcomes only to 2038, the midpoint of the time horizon. For more detailed explanation of the modelling and methods used, please see the Appendices and Bibliography at the end of the document. The sources of the raw data used throughout this analysis immediately follows.

Variables and Sources Used in this Report

Variable	Source
Agricultural Imports (cereals)	Food and Agricultural Organization of the United States (FAO)
Agricultural Imports (meat)	Food and Agricultural Organization of the United States (FAO)
Agricultural Imports (vegetables)	Food and Agricultural Organization of the United States (FAO)
Agricultural Production (crop)	Food and Agricultural Organization of the United States (FAO)
Agricultural Production (fish)	Food and Agricultural Organization of the United States (FAO)
Agricultural Production (meat)	Food and Agricultural Organization of the United States (FAO)
Agricultural Production (total)	Food and Agricultural Organization of the United States (FAO)
Agricultural Production per Capita (crop)	Food and Agricultural Organization of the United States (FAO)
Agricultural Production per Capita (fish)	Food and Agricultural Organization of the United States (FAO)
Agricultural Production per Capita (meat)	Food and Agricultural Organization of the United States (FAO)
Agricultural Production per Capita (total)	Food and Agricultural Organization of the United States (FAO)
AIDS Deaths (Millions)	United Nations AIDS (UNAIDS)
Calories Per Capita Available	Food and Agricultural Organization of the United States (FAO)
Calories Per Capita Available	Food and Agricultural Organization of the United States (FAO)
Change in Education Investment	United Nations Educational, Scientific, and Cultural Organization (UNESCO)
Democracy	Polity IV Project
Diarrhea Deaths (Millions)	World Health Organization (WHO) Global Burden of Disease (2010)
Food Import as Percent of Total Demand	Food and Agricultural Organization of the United States (FAO)
GDP Change	The World Bank (WDI) and International Monetary Fund (IMF)
Gender Empowerment	United Nations Development Programmeme (UNDP)
Government Corruption Perception	Transparency International (TI)
Government Effectiveness	The World Bank (WDI)

Gross Domestic Product (GDP)	The World Bank (WDI) and International Monetary Fund (IMF)
Human Development Index	United Nations Development Programmeme (UNDP)
Human Development Index	United Nations Development Programmeme (UNDP)
Infrastructure Investment	OECD STAN Database, Africa Country Infrastructure Diagnostic (AICD), Congressional Budget Office (CBO), Calderon and Servin (2004), Asian Development Back, the World Bank (WDI), India's Ministry of Economics, Statistics Canada
Lower Secondary Gross Enrollment	United Nations Educational, Scientific, and Cultural Organization (UNESCO)
Malaria Deaths (Millions)	World Health Organization (WHO) Global Burden of Disease (2010)
Malnourished Population	The World Bank (WDI)
Malnourished Population as Percent	The World Bank (WDI)
Other Communicable Deaths (Millions)	World Health Organization (WHO) Global Burden of Disease (2010)
People living in Extreme Poverty	The World Bank (WDI)
Percent of Population in Poverty	The World Bank (WDI)
Population with Access to Electricity	International Energy Agency (IEA)
Population with Access to Sanitation	World Health Organization (WHO) and Joint Monitoring Programmeme (JMP)
Population with Access to Water	World Health Organization (WHO) and Joint Monitoring Programmeme (JMP)
Primary Net Enrollment	United Nations Educational, Scientific, and Cultural Organization (UNESCO)
Respiratory Infection Deaths (Millions)	World Health Organization (WHO) Global Burden of Disease (2010)
Security	Political Instability Task Force (PITF)
Tertiary Enrollment	United Nations Educational, Scientific, and Cultural Organization (UNESCO)
Upper Secondary Gross Enrollment	United Nations Educational, Scientific, and Cultural Organization (UNESCO)

African Development from the Organization for African Unity to Agenda 2063

Over the past five decades Africa has experienced massive transition and change. Shaking free from the burden of colonialism, the continent has invested heavily in key areas of human development. Many of these investments have begun to pay positive returns. For instance, Africans are now more connected than ever, with Regional Economic Communities (RECs) and the African Union (AU) increasingly helping to tie the continent together through shared policy making, diplomacy, and trade. Human development has improved, conflict has declined, and economic growth has increased.

The causes of these shifts are varied, but there have been at least nine major transitions that have helped turn Africa into an attractive source of investment, travel, and an increasingly important player in global politics. These are the following:

1. Structural economic change: The continent has seen a long-term relative shift away from primary good production towards secondary and tertiary good and services production.
2. Debt burden reduction: Debt repayment, forgiveness, and re-structuring programmes have allowed Africa to develop with less fettering.
3. Engagement with the globalized world: FDI, exports, and imports have all risen dramatically.
4. Changes in aid flows: As a share of overall production, aid is generally down from a peak in the early 1990s, leading to less dependence on the outside for development.
5. Improvements in human development: Average years of education have increased, enrollment rates across all levels of education are up, and infant mortality is down.
6. Demographic transition: Reduced fertility rates (driven largely by improved human development) have led to a rising demographic dividend and a maturing population.
7. Improvements in governance: The overall magnitude of domestic conflict in Africa has declined from a high in the early 1990s, and democracy has gained.
8. Leap-frogging with ICT: Instead of investing in costly infrastructure (fixed line telephones, for example), Africa is able to adopt cheaper mobile technology.
9. Peak AIDS Deaths: Though only a recent phenomenon, deaths from AIDS peaked and have been declining, thus improving productivity and reducing burdens on health spending.

Agenda 2063 was initiated by the African Union in June of 2012 within this development context. This vision and strategy document calls for African action to further human development, inclusive growth, and unity. It is a rededication to build upon lessons learned over the past five decades and encourage greater prosperity across the continent. This planning process was established 50 years after the implementation of the Organization of African Unity and promotes African development over the next five decades.

The Agenda 2063 effort is explicitly results-based and emphasizes measurable targets that can be monitored across all major issue areas. It is a comprehensive approach to development analysis that will help shape reasonable expectations about development strategies, priorities, and set these within transparent structures to promote African development by Africans.

This report fits within the framework of Agenda 2063. It is rooted in analysis of the past 50 years, and is a first step in setting continental, regional, and national targets across issue areas.

The key issue areas covered in this analysis align with established AU/NEPAD programmes, each of which has already made progress in setting targets and launching frameworks for African development. In the area of agriculture, the Comprehensive Africa Agriculture Development Programme (CAADP) offers a platform for coordination among RECs and countries, as well as a framework for monitoring and evaluating progress. Their stated targets include increasing public investment in agriculture by at least 10 percent and raising agricultural production by at least 6 percent. Overall, CAADP's goal is to reduce poverty and end hunger via agriculture-led development efforts. In similar fashion, the Second Decade of Education for Africa is the AU's plan for improving the continent's educational systems. The plan includes targets such as the development of national Educational Management Information Systems (EMIS), gender equality, teacher development, greater access to higher education, and improved curriculum, among others.

Africa Health Strategy is the motivational framework that supports Africa's ongoing fight against the burden of disease, disability and premature death. By improving the health of all Africans, this strategy intends to contribute to Africa's overall socioeconomic development. For governance issues, AU member states turn to both the AU/NEPAD Capacity Development Strategic Framework (CDSF) and the African Peer Review Mechanism (APRM). The first strives to increase the effectiveness of African governments, while the latter is a programme that aims to promote higher standards of governance within and among AU Member States and RECs. Finally, the Programme for Infrastructure Development in Africa (PIDA) advances both continental and regional infrastructure goals, especially those related to energy, transport, information and communications technology (ICT) and trans-boundary waters. Spread across various timelines, PIDA also has its own targets for each of these issues. For instance, PIDA aims for 35 percent of Africa's population to have access to electricity by 2020 and to half the amount of people living beyond 2km from an all-season road by 2015, to name a few.

Choosing to prioritize one development policy over another is challenging because trade-offs and opportunity costs are involved. Spending more money on education, for example, requires either taking money from other investment sectors or raising more money through increased aid, taxes, or production. No policy choice leads to purely positive outcomes; negative, unintended consequences should always be anticipated as well. Evaluating and measuring these impacts is a key component of evidence-based policy planning.

No policy choice leads to purely positive outcomes; negative, unintended consequences should always be anticipated as well.

Quantitative analysis and modelling are fundamental to this approach. While not a panacea, these tools can help to shape expectations about the unfolding of human development across key systems and the likely outcomes of policy interventions. The results shown below are not predictions, but rather possibilities, and should be treated as general, macro-level results for the continent in aggregate. Particular development patterns and the impact of specific interventions for different countries and regions will obviously differ.

Macro-scale models can be used for various kinds of policy development, including:

1. Expectations about current development trajectories: These tools can be used to bring stake-holders together to build shared expectations about how issues are developing, and how changes in one issue impact across multiple issues.
2. Customized target setting: Development target setting should consider unique country characteristics. This begins by assessing each country's relative capabilities and then using these assessments to set customized targets.
3. Monitoring and evaluation of development: Because models use standardized databases and variables that are comparable across time and across country, these measurements can help us monitor development and gauge progress towards targets.
4. Evaluating strategic opportunities in policy choice: Choosing one target or policy over another involves trade-offs. A fully integrated model across issue areas and countries can help decision-makers explore these strategic choices for better informed policymaking.

The first main section of this report explores the Current Path of African development at the continental level. This scenario represents an extension of today's policy choices, technological advance, and current understandings of the relationship across key development systems, both within and across countries. The Current Path represents how systems are expected to unfold if Africa pursues existing policies and no major changes occur. Thus, this scenario does not include major shocks—positive or negative—such as a pandemic, transformative growth in artificial intelligence, disruption in energy production, catastrophic environmental event, or any other episode that would significantly change human development trajectories. (The technical appendices include a description of the tool used and the assumptions underpinning the Current Path and the alternative scenarios presented here.)

Despite the promise of already established NEPAD programmes, such as PIDA, CAADP, or the others mentioned earlier in this section, the Current Path forecast, as presented here, does not model their impacts. Certain programmes have received more support than others; yet to date, all of them still lack the kind of universal buy-in that would be necessary to see their influence play out on a continental level. Again, it is this very lack of coordination and policy ownership that the analytical approach demonstrated here might hopefully resolve. By setting targets in an integrated way across various systems, as well as countries, RECs, and the continent, can provide programmes with the consensus and momentum necessary to achieve stated development goals.

After exploring the trends in African development on the Current Path, this report turns to a very preliminary exploration of broad policy interventions across major issue areas. The section gives a sampling of NEPAD's target-setting capabilities. The impact of the alternative policy choices is judged against three key outcome variables: human development, poverty reduction, and overall economic output. True target setting from the AU would require extensive collaboration with civil society, the private sector, RECs, national governments, and key international organizations.

This report demonstrates the powerful technical capability held by NEPAD. Though it forecasts African development at the continental level, this same type of integrated policy analysis could similarly be done at various levels: RECs, national, and, in some select cases, provincial.

The Current Path: Forecasting African Development Today

The **Current Path** of African development is largely positive, though challenges persist. Economic growth rates are high, and production has begun to diversify in important ways for some countries and regions. Human development has generally improved, with more people reaching higher levels of education and deaths from communicable diseases falling, though the increase in deaths from non-communicable disease will present new challenges. The percent of people who lack basic services is generally declining, but, as populations grow, the actual number of people is climbing in some areas. The continent is rich with resources, though stewardship of the environment must remain a priority. Peace and security have improved on the continent especially since turn of the century, which has led to an improved investment environment.

The Current Path: Agriculture and Food Security

The Current Path of African development is largely positive, though challenges persist.

Among the many priorities of the AU, ensuring adequate food for Africa's people is central. Food security is a function of how and where food is produced, the number of calories available for consumption, and how those calories impact health outcomes. Historically, African food production has risen significantly, from around 130 million metric tons in 1963 to 580 million metric tons today. Agriculture production per capita has also increased, though only after the mid-1980s. In addition to this increased production, food imports have also grown. Cereal imports have increased from 5 million metric tons in 1963 to over 50 million metric tons today. The combination of these two trends has led to an increase in calories per capita. In 1963 there were just over 2,000 calories available per person on average across the continent. Today, the average African can access more than 2,500 calories daily.

Year	Agricultural production (million metric tons)	Agricultural production per capita	Agriculture Imports (million metric tons)	Calories per Capita
1963	133.9	0.48	5.4	2,033
1978	185.3	0.45	18.2	2,156
1995	321.9	0.49	33	2,344
2010	548.1	0.57	59.8	2,535

Figure 1: African agricultural and caloric development

Despite the growing abundance of calories available, Africa lags behind the rest of the world considerably. On a per capita basis, 2,500 calories was the world average (including Africa) in the mid-

1980s. On the Current Path, Africa is not expected to achieve the current world average levels until the middle of the century.[2]

The geography of food production is also an important determinant of food security. World food production and distribution take place in a highly globalized food system. That creates external food dependence in many countries that potentially reduces their food security, especially if there is volatility in production elsewhere. On average, African countries now import around 12 percent of their food. Indeed, of all countries within the AU, only three are net exporters of food.

Without policy changes, this external dependence will only increase on the Current Path. By the end of Agenda 2063 nearly 40 percent of all food consumed in African countries will be imported. (See this report's section on the Agriculture Push to explore how such trends could be reversed.)

	Calories Per Capita	Undernourished Population (millions)	Food Import as % of Total Demand
2014	2,536	214	12%
2025	2,608	228	25%
2038	2,699	234	31%
2063	2,973	170	38%

Figure 2: Forecast of food security in Africa

As past experience demonstrates, producing and accessing food is not enough. When evaluating food security, the quality of the calories eaten and the health of individuals must be taken into consideration. Poor performance in this respect largely happens in two ways. First, calories consumed can be from increasingly poor sources. Diets heavy in salt and fat can provide ample calories, but they also increase non-communicable diseases like diabetes, cancer, and heart disease. Second, poor access to water and sanitation can drive increases in diarrheal disease, which generally undermines the positive health benefits of increased caloric intake.

Modeling constraints prevent us from measuring increases in salt- or fat-rich diets directly, but increased household incomes would lead to higher instances of non-communicable disease. At the same time, the number of malnourished people in Africa is large and growing. These forecasts suggest that this growth will persist over the next four decades, even as the percentage of those lacking calories falls. For instance, more than 200 million people are undernourished today, and more than 240 million people are forecast to fall into this category by 2040, before this trend declines.

One key step to mitigating these high levels of undernourishment is to follow the lead of the Comprehensive Africa Agriculture Development Programme (CAADP), which has already set important

[2] Agriculture is modeled in both supply and demand terms for crops (used for consumption, feed, or industry) as well as meat and fish production. Land use (broken down into five sub-types) changed dynamically based on change in investment and crop yields are driven by climate change, investment, and exogenous improvement in technology. This sub-model could be enhanced by adding a more explicit representation of fresh-water aquaculture. It is, as with all sub-modules, dynamically connected to all other aspects of the model for all countries over time.

investment growth targets in this area. With broader continental, REC-level, and national buy-in, programmes like CAADP can be used to advance towards a more optimal situation.

The Current Path: Education

The integrated analysis presented later in this report shows the lasting positive effects of potential improvements to education on Africa's future.

It is well established that education is a fundamental pillar of human development. Educational outcomes within the continent have improved from 1963 to the present; Africa has seen the average years of attainment for someone 25 years or older grow from just over one year to around five years. Primary net enrollment rates have also grown significantly, increasing from just over 45 percent children entering school at the appropriate age to nearly 75 percent today. It is not just the youngest who have increased their educational attainment: tertiary gross enrollment has also grown from just less than 1 percent of the total population to nearly 10 percent.[3]

According to the Current Path forecasts, this progress should continue. Given historical trends up to now, primary net enrollment—the percent of age-appropriate children enrolled in school—is forecast to grow from 75 percent today to over 95 percent by the 2040s. Lower and upper secondary gross enrollment could also grow from 55 and 45 percent respectively to over 90 and 80 percent by the end of this time horizon. Tertiary gross enrollment also rises. In 50 years, it's reasonable to expect that 30 percent of Africans would go to university.

[3] The education model of IFs represents primary, lower and upper secondary, tertiary enrollment, throughput, and graduation for males and females. We forecast outcomes as a function of government spending and current patterns of development. The model does not represent educational quality explicitly, largely because global comparative data on this is under-developed. See the bibliography for sample publications focusing on this sub-module.

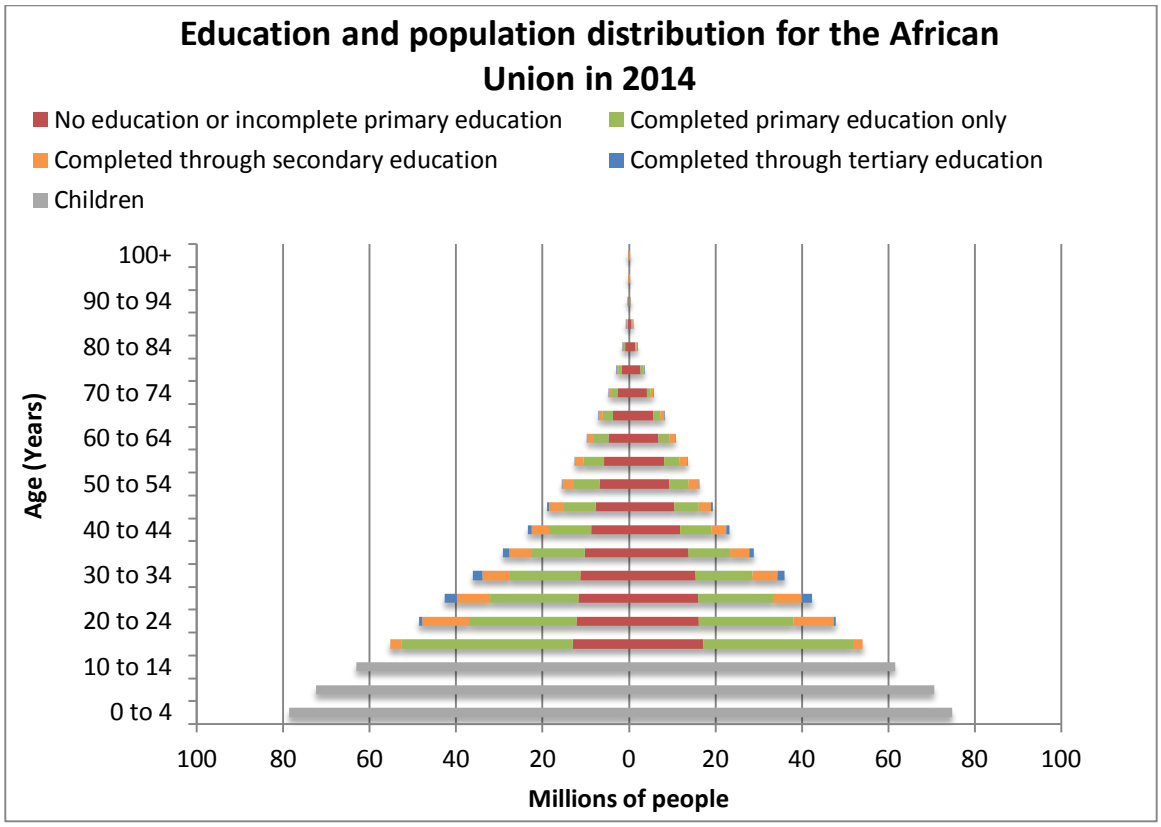


Figure 3: Education and population distribution for the African Union in 2014

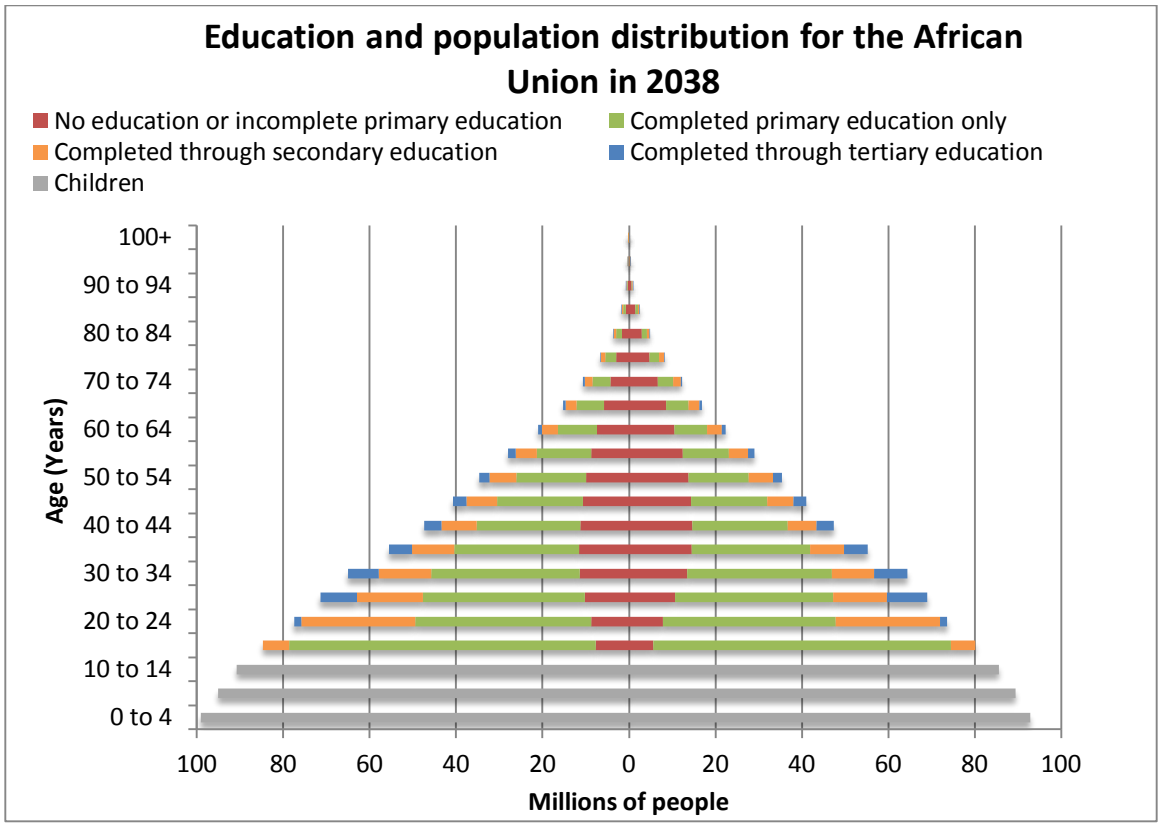


Figure 4: Education and population distribution for the African Union in 2038

While investment in human development has begun to pay off, there is much to accomplish as a continent. Indeed, as those familiar with the AU's First Decade of Education for Africa framework have recognized, many Member States have not yet achieved their goals in this area, even despite major efforts. This in part stems from a lack of cooperation among African actors and partners, as well as a shortsighted failure to integrate education efforts within other systems. This is a massive development challenge for the continent, and any child not currently enrolled in school represents a constraint on African development.

In 2013, nearly 55 million primary-school-aged children were not attending school, and even with the existing framework for improvement that drives progress on the Current Path, it's not likely that today's global average for education years will be reached until after 2050. It's equally unlikely that primary net enrollment would rise to 90 percent until nearly 2040. That is, of course, unless the continent adopts bold changes to policy soon. The integrated analysis presented later in this report shows the lasting positive effects of potential improvements to education on Africa's future.

The Current Path: Governance

Governance can be characterized in three ways: security, capacity, and inclusion. Historically, African governments have improved in each of these areas. At the establishment of the OAU, rates of domestic conflict were relatively low—about where they are today. Security challenges grew significantly and peaked into the early 1990s. Since then, however, a clear decline in domestic conflict can be seen. In

terms of governance capacity, Africa has witnessed a reduction in government revenue as a percent of GDP. Meanwhile, African nations have experienced a simultaneous decrease in the percent of government revenue coming from external foreign aid. This is a hopeful sign that the continent has begun to stand on its own feet by meeting internal fiscal needs. In terms of inclusion, average democracy levels declined from the foundation of the OAU to the end of the Cold War, after which they experienced large and sustained gains up to the present.

While peace and security concerns do still exist in certain areas, the AU's creation of a Rapid-Reaction force is an important signal that this is a priority at even the highest levels of policymaking.

While these improvements are impressive, much work remains, particularly in areas of peace and security. The AU's creation of a Rapid-Reaction force is an important signal that these concerns are a priority at even the highest levels of policymaking. Corruption and the quality of governance are other factors that create unstable investment environments in Africa. There is also much room to improve in areas such as gender empowerment and democratic participation.

Below, one can see how Africa compares in all these measures to the rest of the world, particularly the most developed nations.

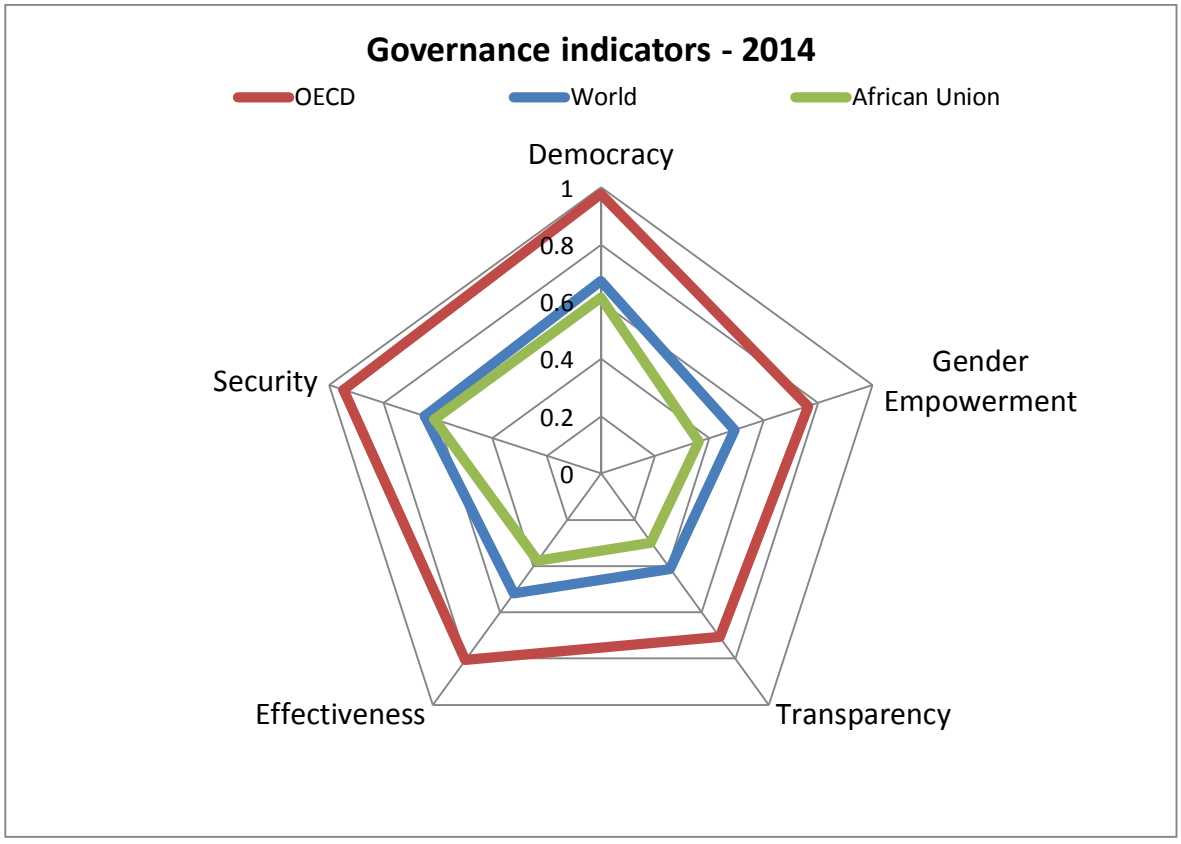


Figure 5: Various measures of governance in 2014 - Africa, OECD, and the World

Even despite the challenges facing governments today, the Current Path forecasts improvement in security, capacity, and inclusion for Africa; though, this is not immediate.[4] Security should improve, possibly reaching the same levels now seen across South East Asia by the mid-2030s. Capacity-building improvements in transparency, governance effectiveness, and regulatory quality can all be expected. Democracy and gender empowerment should also continue to rise in Africa. However, by late in the time horizon, the Current Path would only put Africa on par with Latin America and the Caribbean today.

The role of the state in improving development is significant for African countries and regions (see, for example, the UNECA report on the Developmental State). Tools have already been put in place to further enhance this. For example, the African Peer Review Mechanism's focus on democracy and political governance, economic governance, corporate governance, and socio-economic development should remain a foundation of African governance enhancement across time.

As a separate issue, forecasts suggests that given the extent of past revenue-collection issues, leaders within the AU will likely continue to confront problems in collecting higher levels of government revenues, particularly when such revenues are considered as a share of GDP. That said, overall, government revenues should grow slowly on the Current Path, even as foreign aid (now a significant share of GDP) declines.

The Current Path: Health

People in Africa have long suffered from a wide range of poor health conditions, yet in recent decades, the burden of communicable diseases—such as AIDS or malaria—has seemingly drawn the most attention from the global community. Sadly, this is not without warrant. Over 1.6 million people died each year at the peak of the AIDS epidemic in 2004 and 2005. Even as recently as 2010, nearly 1.3 million people died from communicable respiratory infections (including tuberculosis), around 900 thousand people died from communicable diseases related to diarrhea, nearly 700 thousand died from malaria, and over 2.8 million people died from other communicable diseases, which includes maternal deaths. In that same year Africa accounted for 46 percent of deaths from global communicable diseases but only 9 percent of those from non-communicable diseases.

> The story of African health development is mixed. On one hand, the continent is poised to continue to improve health outcomes related to communicable disease. On the other, increases in non-communicable disease deaths will create a situation over the coming decades referred to the double-burden of disease.

The Current Path paints an optimistic picture about Africa's ability to continue to reduce the communicable disease burden.[5] In fact, these deaths drop by half over the next four decades (from

[4] The socio-political, or governance, sub-module measures change in a range of variables associated with governance security, capacity, and inclusion. There are internal connections within governance systems as well as forward linkages from changes in governance to other model systems. See the bibliography for relevant publications.

[5] The health model of IFs represents mortality, morbidity, and years of life lost to disease disaggregated into 15 diseases and disease clusters. These are grouped into three categories: 1) communicable diseases: HIV/AIDS, diarrheal diseases, malaria,

approximately 7 million today to 3.5 million in the early 2040s). While this reduction is significant, other health challenges are on the rise. Non-communicable diseases—the causes of death that are often associated with higher standards of living and increased caloric intake, like heart disease and cancer—are set to grow substantially. Currently less than 35 percent of African deaths are from non-communicable diseases. Without significant changes in policy, that number could grow to over 60 percent of total deaths by 2050. In addition, deaths from traumatic injuries are forecast to grow—suffered in traffic accidents in particular—to increase from less than 10 percent of total deaths today to over 15 percent by 2050, reflecting an increase in car usage that outpaces regulatory frameworks, infrastructure, and the solidification of traffic norms.

Thus, the story of African health development is mixed. On one hand, the continent is poised to continue to improve health outcomes related to communicable disease. On the other, increases in non-communicable disease deaths will create a situation over the coming decades referred to the double-burden of disease. Health systems will be forced to adapt to both kinds of health concerns. However, even with these significant challenges, the Current Path forecast suggests that African life expectancy might grow from less than 60 years today to 75 years by the centennial anniversary of the Organization of African Unity.

The Current Path: Infrastructure, Energy, and the Environment

The extractive nature of colonialism in Africa produced infrastructure that still draws resources out of the continent to its ports. The map below highlights the number of shared national-level border crossings in Africa and the world. It is clear that Africa generally lags behind the rest of the world.

respiratory infections, and other communicable diseases including maternal mortality, 2) non-communicable diseases: cancer, cardiovascular diseases, digestive disorders, respiratory conditions and diseases, diabetes, mental health, and other non-communicable diseases, and 3) injuries: road traffic accidents, unintentional injuries, and intentional injuries. It represents both distal (e.g., average income and educational attainment) and proximate (e.g., cook-stoves, air pollution, and smoking) drivers of these health outcomes.

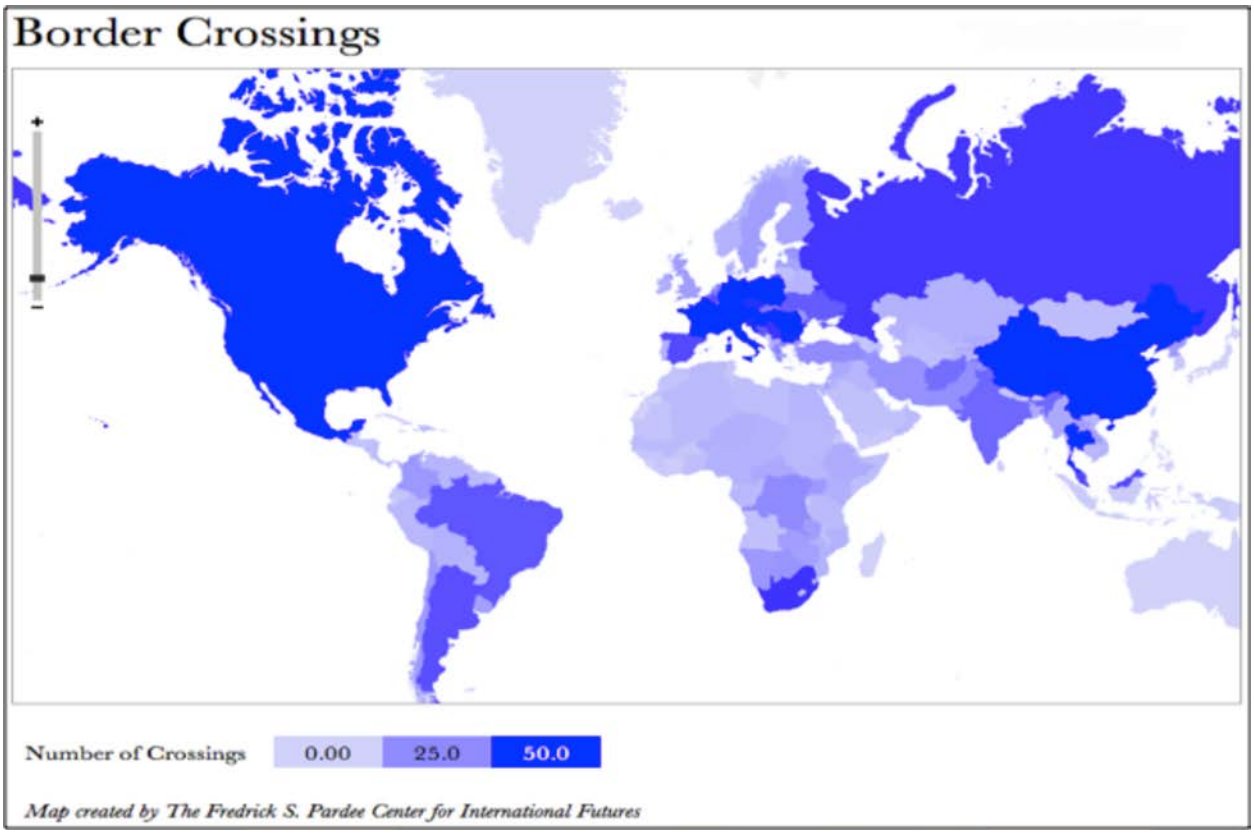


Figure 6: Number of border crossing nodes shared with neighbors

In addition to improved avenues for intra-African trade, we have seen ongoing advances in other forms of physical infrastructure as well. The percent of African population with access to electricity increased from 35 percent in 2000 to over 40 percent today (Note: Long historical series are seldom available for infrastructure variables).[6] Total road length has increased from 950 thousand kilometers in 1963 to over 2.4 million today. Access to improved sanitation increased from 177 million people in 1990 to over 400 million Africans today. In 1990, fewer than 20 million had piped water to their home; today over 50 million have this service. Most pronounced, however, is the number of mobile phone subscriptions: in 2004 there were just over 50 million mobile phone subscriptions on the continent. Now that number is rapidly nearing one billion.

In 2004 there were just over 50 million mobile phone subscriptions on the continent. Now that number is rapidly nearing one billion.

[6] Infrastructure forecasts are primarily across four general sectors: electricity, water and sanitation, road transportation, and information and communication technology. The demand for each infrastructure type is calculated and compared with available resources. New infrastructure is built and old infrastructure maintained when sufficient resources are available (and there is competition within the governance finance model from other sectors, such as education, health, military, general administration, and research). The current tool can be improved by making the relationship between public and private financing more nuanced, as well as adjusting infrastructure construction costs across time and region.

However, while access has improved, current levels remain far below world averages. Population growth will only increase the number of Africans without basic infrastructure. For instance, more than 580 million Africans do not have access to electricity, and this number is forecast to climb to roughly 600 million by the 2020s. Moreover, roughly 300 million people don't have access to an all-weather road within two kilometers of their home, severely limiting their access to other important resources like education, healthcare, and markets. By the 2030s, 370 million Africans could face the same dilemma. The population with no access to safe sanitation has also increased from over 300 million in 1990 to beyond 440 million today (marking a decline in the percentage without access, but an increase in total individuals). This figure is forecast to grow to over 480 million by the mid-2020s. Safe water access measures tell a similar story: in 1990 over 250 million people had no access to safe water. This has increased to over 330 million people today and could reach 360 million people by the mid-2020s as well. While ICT has shown rapid improvement, there are currently only 99 million mobile broadband subscriptions on the continent.

Energy resources could also be an important source of African wealth on the Current Path, as well as in other policy scenarios.[7] Despite the political complexities that belie extraction efforts throughout the continent, fossil fuels and mining resources are widely available. New developments in the extractive resource fields now make it possible for Africa to produce even more resources for global trade and domestic use.

The Current Path includes an increase in natural gas production across the continent due to hydraulic fracturing, more commonly known as "fracking." This method of natural gas extraction can get to pockets of natural gas that are not cost effective to access with traditional methods. Environmental risks introduce significant uncertainties about the extent that this method of gas production could be used in Africa's future.

These forecasts indicate that, given current policy, the globe will eventually move beyond fossil fuel energy production and towards renewable energy sources. Currently, renewable energy production is a very small share of overall global energy production: beyond hydroelectric sources, renewable production accounts for just over 2 percent of total global energy today. However, this small share of production could grow rapidly as the cost of producing renewable energy declines and the technology associated with treating intermittent production improves.

Africa's energy production from renewables is less than half of one percent of the total energy produced. The Current Path suggests that renewable energy production could represent as much as 10 percent of total African energy production by the late 2030s. This might take the form of bio energy or

[7] Energy forecasts consider traditional (oil, gas, coal, hydro, nuclear, renewable) and non-traditional (oil and gas from fracking) sources of energy. The model begins by measuring ultimately recoverable reserves, then what is technically and profitable for recovery, and then compares this with demand in order to drive production. Energy consumption then drives carbon emissions and build-up in the atmosphere which then leads to changes in temperature and precipitation. Again, see the appendices for more technical information.

other renewable energy infrastructure projects, such as those currently promoted by NEPAD's PIDA programme.

The global difficulty of renewable energy adoption on a very large scale coupled with poor incentives for mitigation of global greenhouse gas emissions mean that climate change will become an increasingly large problem for the continent. While great variation exists in the ways in which carbon emissions will impact Africa, on average, temperature is forecast to increase relative to 1990 levels by over 2 degrees Celsius by 2063. In addition, 0.24 percent less precipitation is forecast. However, note that this differs widely for countries in Africa. At the high end, some countries would experience as much as a 2.5-degree (Celsius) increase while countries with less growth would see an increase of around 1.5 degrees. For the high end of precipitation some countries are forecast to increase precipitation by over 12 percent. Alternatively, other countries in Africa could see a decrease by the end of the 50-year time horizon by as much as 12 percent. See the figure below for this impact on African regions.

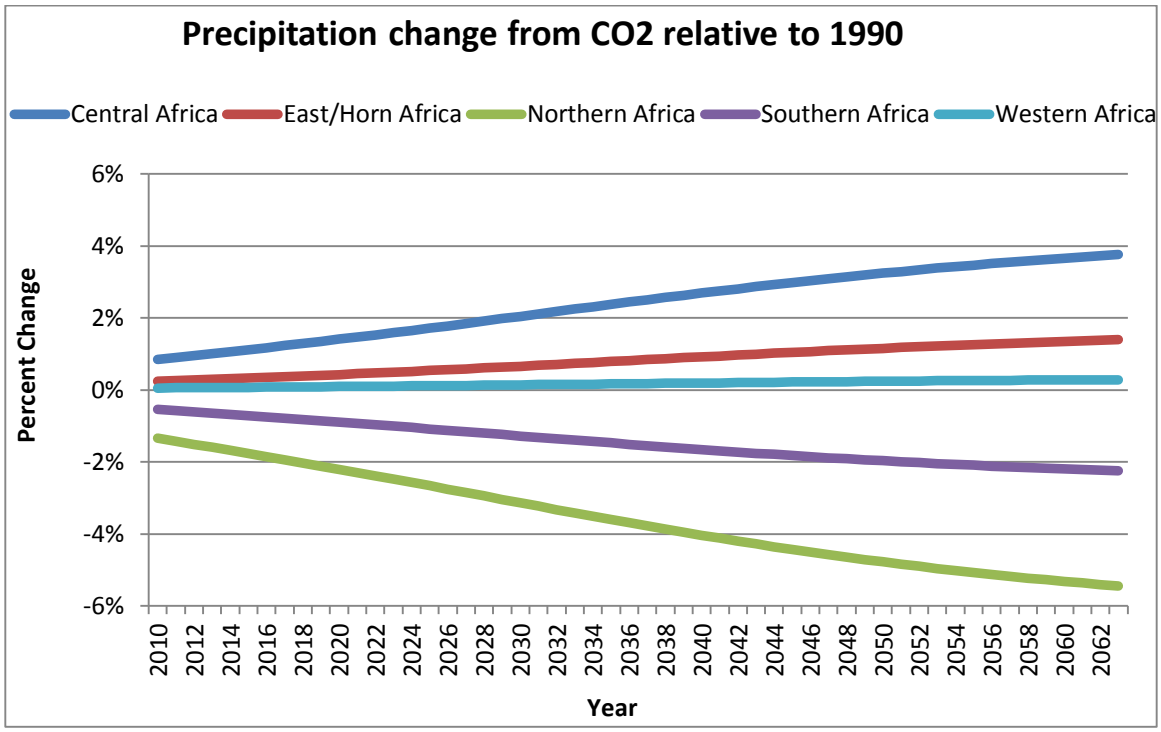


Figure 7: Precipitation change for AU Regions relative to 1990 levels

These changes in temperature and precipitation lead to impacts across all natural systems, particularly agriculture. Indeed, relative to 1990 levels of hectare yield, climate change could reduce the average annual output on a fixed piece of land by 7 percent by the end of the time horizon. This, however, does not necessarily mean that agricultural yields will decline, as improvements in technology and fertilizer can often counteract the impact of changing temperature and precipitation. Still, increasing agricultural yields may become more expensive.

Climate change will likely lead to widespread challenges for the continent, many of which are impossible to forecast. On the Current Path, the build-up of carbon in the atmosphere will likely continue, as there

is no global consensus for wide-scale mitigation programmes. Not to mention, current levels of renewable energy production are often cost prohibitive and face challenges in intermittency and lack of infrastructure. That said, there are additional variables that could be added to enhance how the impacts of climate change are forecast in Africa. For example, there is an expected link between changes in temperature, precipitation, and the frequency and intensity of extreme weather events. With this type of integrated policy analysis, NEPAD has the capacity to explore these linkages.

PIDA's established infrastructure targets are already motivating improvements in the infrastructure, energy, and environment system. For example, there has been much progress stemming from the Priority Action Plan, which calls for a 68 billion USD initiative to implement 51 infrastructure projects over the next decade. With more commitment to programmes like PIDA from continental, regional, and country-level stake holders, could produce even more significant impacts in this area.

Integrated Policy Analysis: Introduction

The sections above explored the Current Path of African continental development across the Agenda 2063 time horizon. Such forecasts support popular notions that Africa is rising, and continental organizations can—and indeed should—set their expectations around continued growth and development. In short, if Africa keeps pursuing the policies that it has, the future will likely be brighter than the present.

No organization should strive for the status quo (or even the status quo in rates of improvement) if there are reasonable but aggressive alternatives that lead to more rapid increases in development.

That said, no organization should strive for the status quo (or even the status quo in rates of improvement) if there are reasonable but aggressive alternatives that lead to more rapid increases in development. The following section outlines some of these alternatives, exploring the strategic options available for African policymakers today.

What if Africa took education, for example, as an area of prioritization? What kind of investment would be needed, and what would be the spillover effects? How would prioritizing investment in education impact outcomes in a different sector, like health? This section begins by highlighting five distinct issue areas within this forecasting approach, evaluating which kinds of big policy interventions—each of which is described here as a "Push"—are possible and what some of the important forward impacts might be. While each sub-section focuses on the effects related to that policy area, the strategic choices are made comparable by exploring the impact on the HDI, extreme poverty, and overall national production.

The final sub-section asks about the impact of aggressively pursuing each of these five development policies simultaneously. Again, note that in the following sections, the forecasted outcomes of each Push are compared to those of the Current Path. To that end, it's important that any numbers or figures are not interpreted as targets in themselves, but rather as the potential impacts—in relative terms—of targeted policy. Each of the modelling interventions used in this process is identified in Appendix 1.

Integrated Policy Analysis: Agriculture Push

As detailed earlier in this report, Africa currently experiences poor food security, a problem that can be expected to continue. In the **Agriculture Push**, food security is evaluated by modelling improvements in African agriculture-related outcomes, which depend on improved yields, increased land under cultivation, increased investment in agriculture, and increased demand for food. These forecasts also represent policy interventions that would directly transfer food to the most vulnerable, poor, and undernourished. Although these forecasts consider such interventions on a broad, operational level, the task of designing and implementing actual laws, regulations, and political tactics to achieve them in practice remains within the hands of policymakers and institutions, such as national governments or programmes like CAADP.

An Agriculture Push could lead to an increase from 2,800 (Current Path) to 3,600 available calories per person by 2050.

These forecast suggests that the interventions mentioned above would lead to a significant increase in calories available per capita (more than 3,600 calories available from the Agricultural Push in 2050 compared to 2,800 in the same year on the Current Path), a slowing growth in dependence on the outside world for production, and a reduction in the number of undernourished people in 2040 from 230 million on the Current Path to less than 60 million. The increases in yield, land placed under cultivation, investment, and demand is all within historically reasonable levels. The two figures below show the relative increase in food production for African consumption and reduction in undernourished people between the Current Path and Agricultural Push.

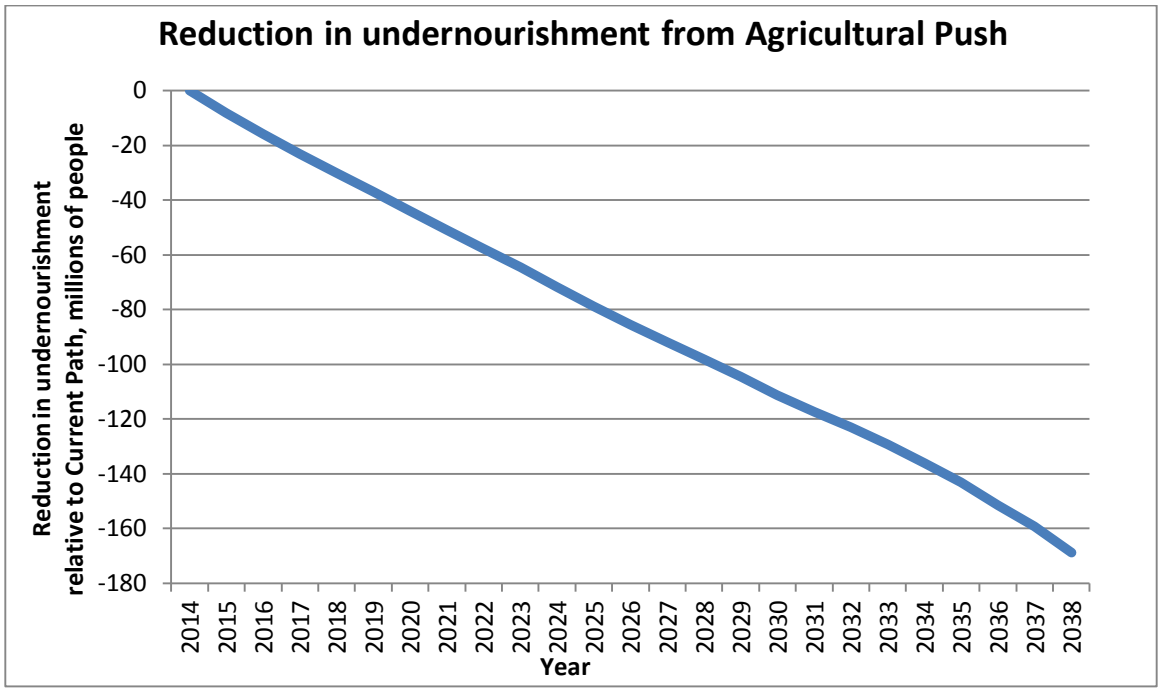


Figure 8: Reduction in undernourished population in the Agricultural Push

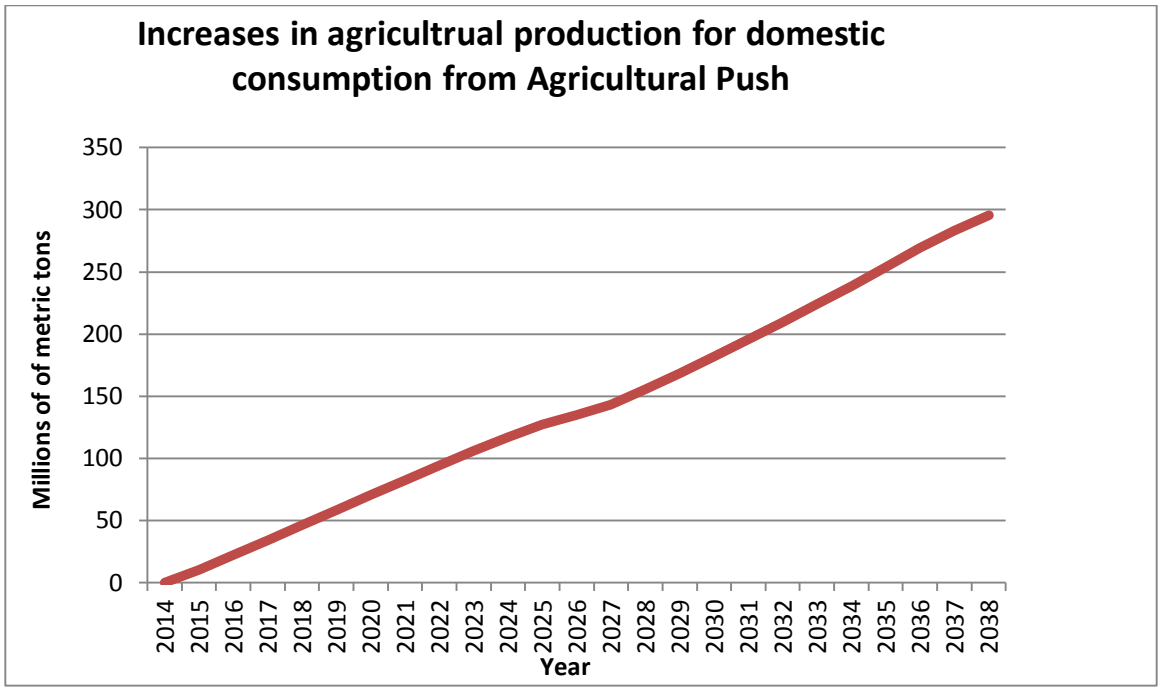


Figure 9: Increase in food production for African consumption in the Agricultural Push

Even though positive impacts from these policy interventions can be seen, it must be noted that such investment in agriculture is not without cost. To achieve these kinds of gains, capital has to be shifted from other sectors of the economy to agriculture, including those sectors that add more overall value per investment. In the Agriculture Push, capital resources are transferred into a sector that is relatively less efficient for overall output. Thus, in the very long run (2040 to 2063), while more people are much healthier, the economy is not as efficient, leading to slightly lower overall production. For instance, while the scenario forecasts relative increases in economic output in the earlier years, by 2063, the resulting inefficiencies could actually spur a relative decrease in GDP, compared with the Current Path. This also leaves human development, as measured by the HDI, relatively unchanged over the longer term.

Still, the push to improve agriculture does have a substantial impact on the number of people living in extreme poverty, defined as less than $1.25 USD per day. With such advances in agriculture, one could expect more than 45 percent fewer people living in extreme poverty by 2038, compared with the Current Path.

Integrated Policy Analysis: Education Push

As discussed above, one could certainly expect education to improve on Africa's Current Path. However, a push to prioritize improvements in this area is indeed possible and could deliver even more positive returns. Already, there has been a renewed effort to achieve progress under the action plan outlined by the AU's Second

This investment in education draws resources from other productive aspects of government spending… However, this investment produces a substantial return in the long term.

Decade of Education for Africa.

To better understand the far-reaching impacts of well-implemented education policy, an **Education Push** was modeled by increasing how rapidly students enter the education system within the first year of the time horizon, later improving enrollment and graduation for all levels, at historically reasonable rates. The line graph below tracks the difference between the Current Path and the Education Push across time. There is significant initial growth in primary, lower secondary, and upper secondary enrollment that begins to plateau after three decades, as these measures begin to reach the upper limits of near-universal enrollment. Growth above the Current Path in tertiary enrollment begins less aggressively—partially because increases in tertiary enrollment are a product of more students graduating secondary education—but this trend advances more steadily across time.

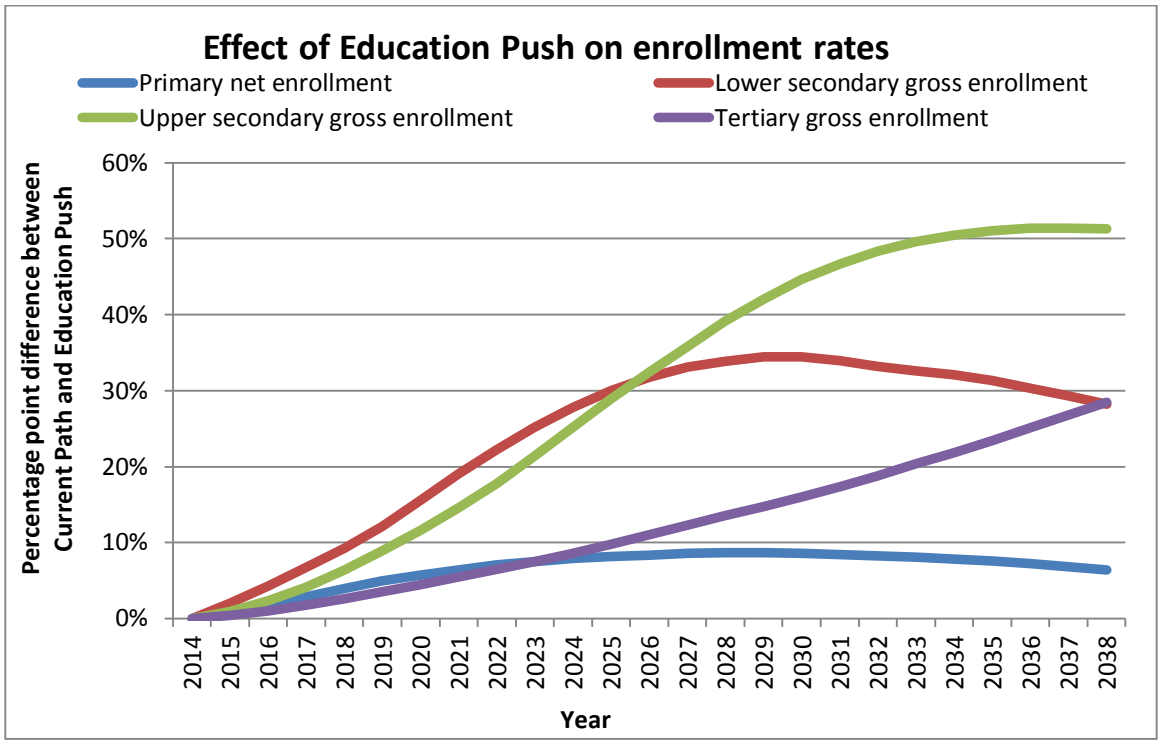


Figure 10: Increases in enrollment rates across four education levels from an Education Push relative to the Current Path

Despite the obvious gains, this Education Push is costly. In the Current Path, Africa spends an increasingly large share of GDP on education, growing from 4.2 percent of GDP to over 4.4 percent of GDP by the middle of the time horizon. In the Education Push, by contrast, some of the increase in expected education spending growth is front-loaded, and reaches levels above 5 percent by the mid-2020s. In fact, in this forecast, African education spending would grow by over $10 billion USD by 2020

and over $30 billion USD more than the Current Path in 2030. This investment in education draws resources from other productive aspects of government spending. In this case, expenditures in vital areas, such as health, infrastructure, and domestic security, were all reduced relative to the Current Path.

However, this investment produces a substantial return in the long term. Figure 11 shows the difference between the Education Push and the Current Path for both education spending and GDP. As it indicates, initial investment doesn't bear net returns until later, once students work through many years of formal education and enter the work force.

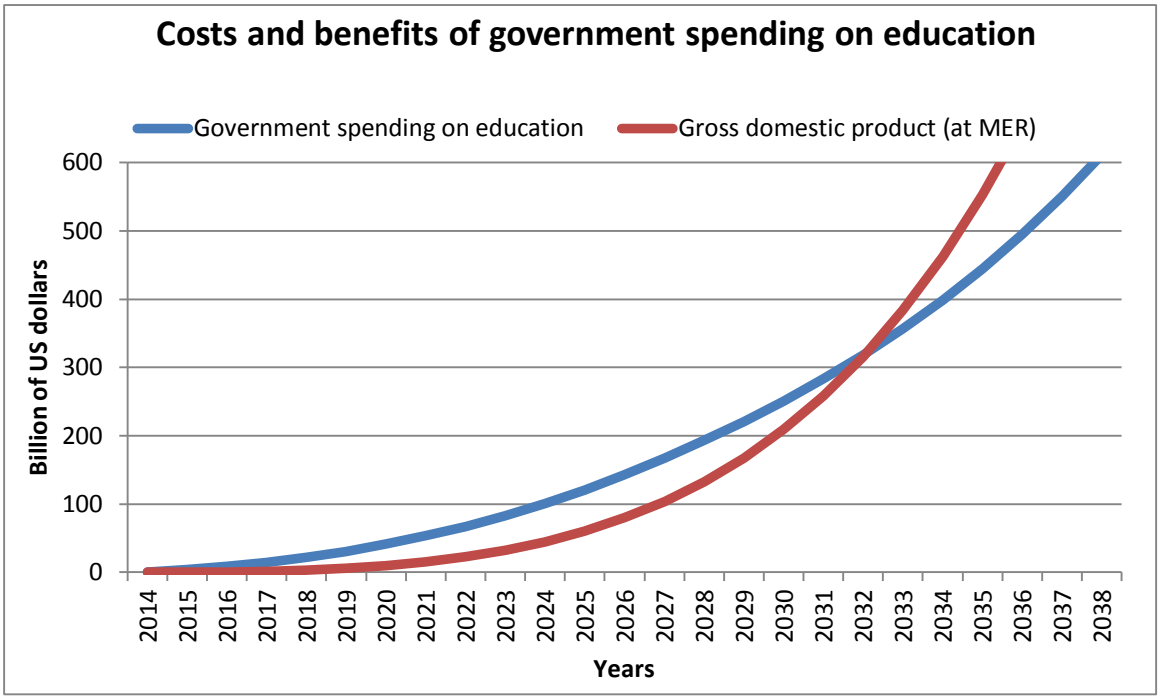


Figure 11: A cost benefit analysis comparing the effects of an Education Push relative to the Current Path.

Some of the additional positive spillover effects from the Education Push can be seen in other areas of human development. For instance, relative to the Current Path, HDI should improve across the time horizon, the number of people living in extreme poverty could drop by more than 20 percent by the middle of the time horizon, and overall national production (GDP) could grow by roughly 8.5 percent more by the end of the time horizon.

Integrated Policy Analysis: Governance Push

The Governance Push models improvements in five related areas: transparency, effectiveness, security, democracy, and gender empowerment. By focusing on governance, Africa could reap great rewards for the continent. This analysis of historical trends suggests that large improvements to governance are certainly possible across the continent, especially given these forecasted reduction in

Improving governance is, in many ways, low-hanging fruit for African development, though it is fraught with political complexities.

destabilizing events and security issues. Significant improvements in capacity and inclusion could also bring about positive change. The following radial diagram shows these forecasts for African governance development in the Current Path and in the Governance Push in 2038.

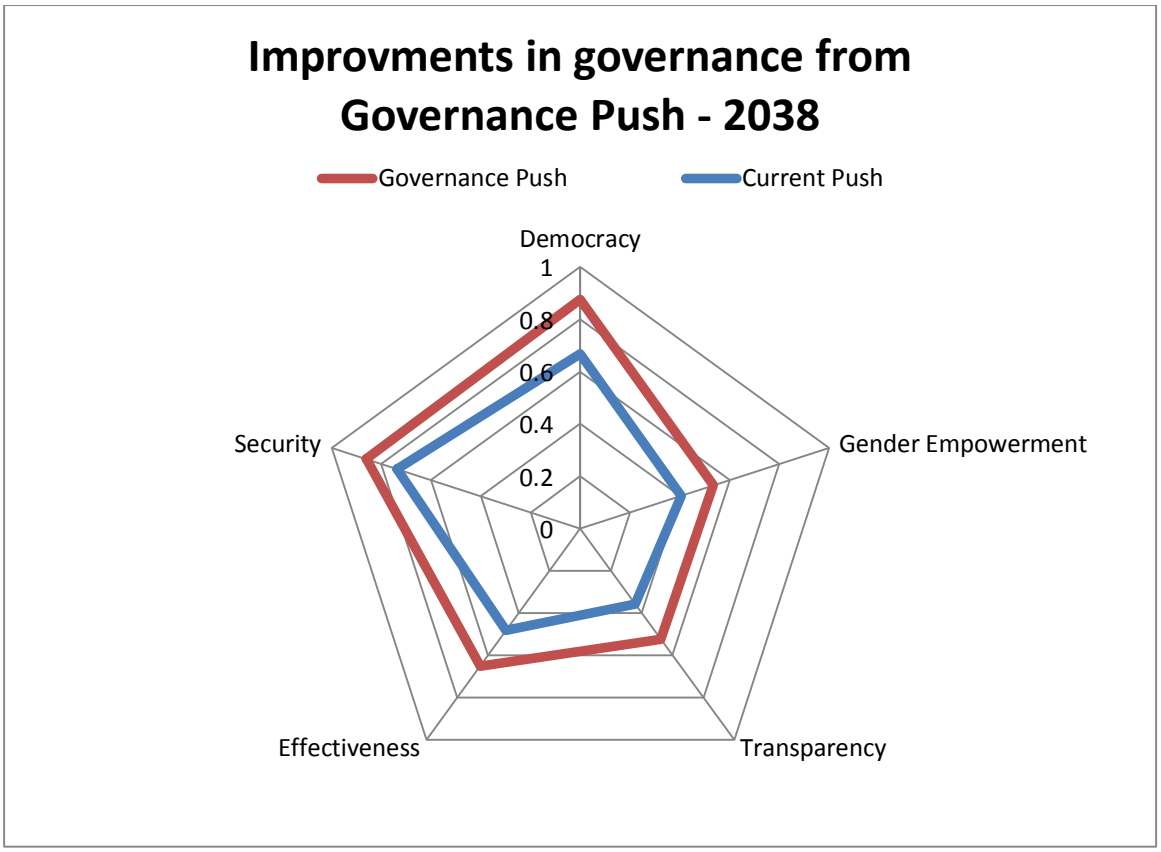


Figure 12: Improvements in security, transparency, democracy, gender empowerment, and effectiveness in 2038 from a Government Push, relative to the Current Path.

Improving governance is, in many ways, low-hanging fruit for African development, though it is fraught with political complexities. Making budding bureaucracies efficient and less corrupt is challenging. Reducing domestic conflict is not straightforward, and increasing the participatory voice of the population—minorities, women, or the general public—won't be easy and may lead to unintended consequences.

The Governance Push identifies the relative impact of improving governance on the variables of interest. On all measures improvement is driven largely by the enhanced ability of governments to promote greater social productivity and overall output. By strengthening governance in the aforementioned ways, GDP, for example, could be almost 14 percent higher than it is on the Current Path by 2038. This improvement also impacts other variables, such as the number of people living in extreme poverty, which falls considerably—by as much as 19 percent in the same time horizon, compared to the Current Path.

Integrated Policy Analysis: Health Push

Given its palpable effects on human well-being, African leaders have already made health a top priority in their development efforts. Here, the impact of a concentrated **Health Push** is shown for the continent. As in the other sections of this report, this analysis only considers what happens if certain metrics, specifically dealing with the disease burden, go up or down. It's still up to continental leaders and policymakers, such as those involved in implementing the Africa Health Strategy, to determine which specific laws and policy tactics might achieve such broad interventions. Figure 9 shows the cumulative number of deaths averted in the Health Push across the communicable disease category. The deaths avoided include 10.8 million from AIDS, 2.4 million from diarrhea, and 15.4 million from other communicable diseases (which includes maternal mortality), among others. Altogether, the Health Push could save upwards of 54 million lives (Note: This chart does not display all possible causes of death that are modelled in IFs).

African leaders have already made health a top priority in their development efforts … it's still up to continental leaders and policymakers, such as those who have already done much to develop the current Africa Health Strategy, to determine which specific laws and policy tactics might achieve such broad interventions.

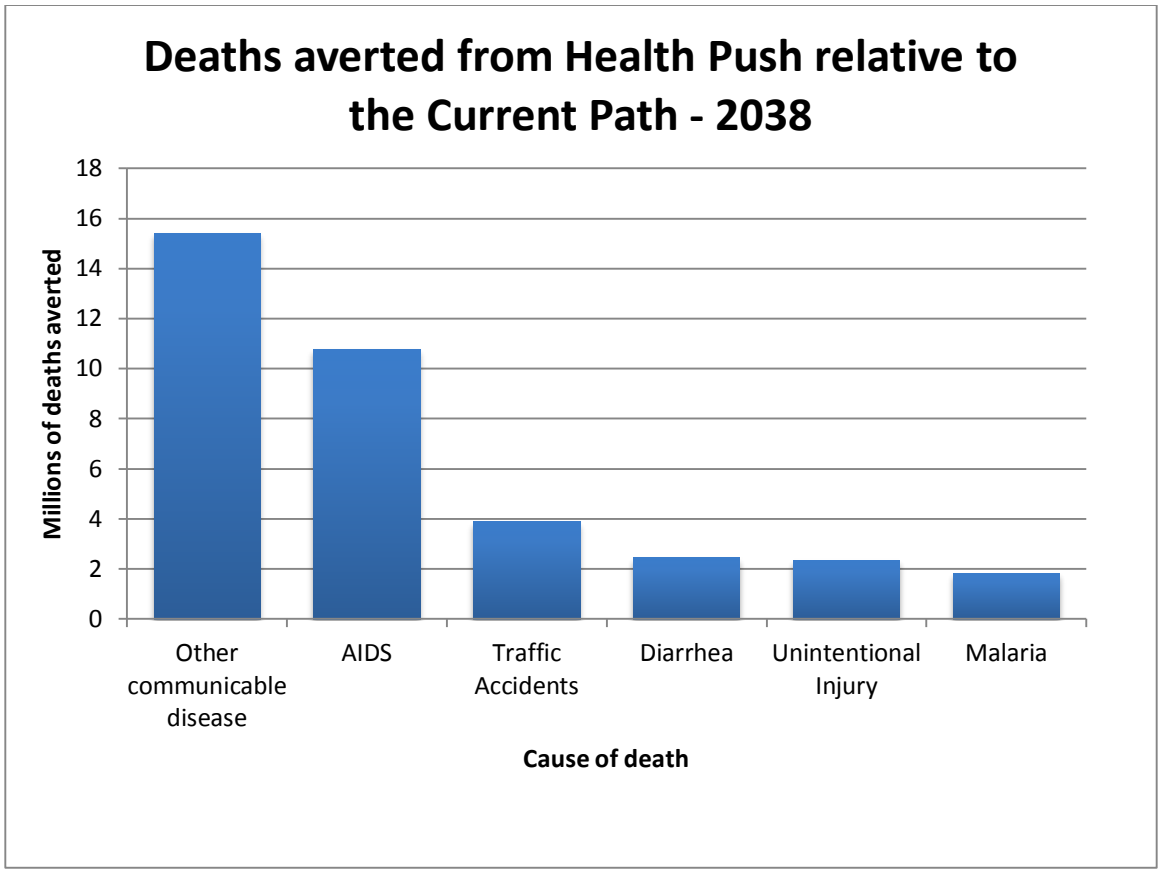


Figure 13: Deaths averted in 2038 from a Health Push, relative to the Current Path.

Reducing deaths below the expectation of the Current Path has significant spillover effects. Life expectancy increases above the Current Path by about two years for most of the time horizon, implying additional improvements in the quality of life. HDI could improve from the Current Path by roughly 5 percent by the middle of the time horizon. Because healthier people are generally more productive, overall GDP is forecast to increase by nearly 7 percent by 2038. Nevertheless, even with the potential reduction in fatalities and continent-wide improvements, African policymakers likely won't reduce extreme poverty by as much in the Health Push as in the other scenarios. After all, while more people would live longer over the 50-year time horizon, continuing inequality among a larger living population would likely constrain governments' ability to mitigate extreme poverty.

Integrated Policy Analysis: Infrastructure Push

Since it provides the physical backbone for many other development systems, it's likely that African governments will look to invest in infrastructure moving forward. The Infrastructure Push increases investment in the following sectors: electricity, roads, water and sanitation, and information communication technology (ICT). However, for this brief, the increased access to these services is modeled not in a universal way, but instead using a method called Standard Error Targeting. This type of benchmarking begins by making the assumption that countries should be investing in the infrastructure types that they lack the most. This is a customized targeting approach that doesn't ask countries to achieve universal access to everything, but instead to improve access where it is relatively the poorest.

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Relative to the Current Path, the Infrastructure Push greatly reduces the number of people who lack access to basic services. By the middle of this time horizon, these forecasts suggests that more than 200 million more people would have access to electricity and improved sanitation than on the Current Path, and over 100 million more people would have access to improved water. By 2063, 50 million more people could have access to improved roads in this scenario.

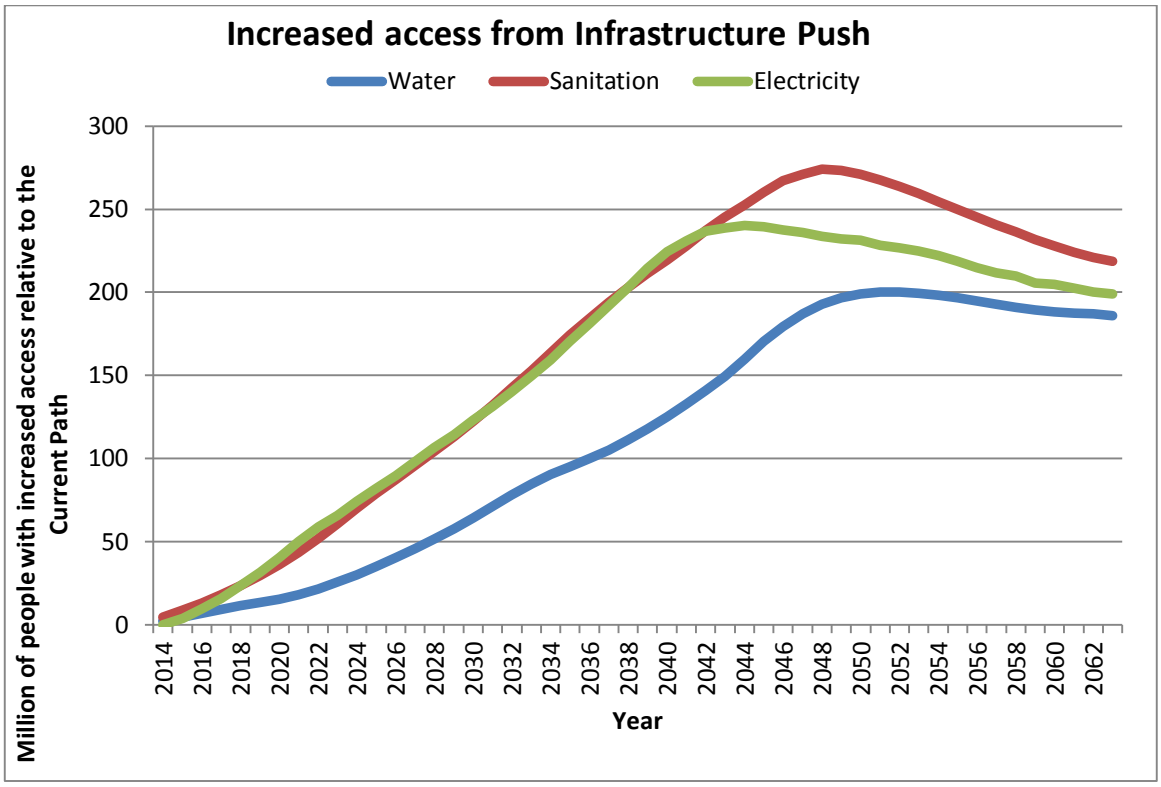


Figure 14: Increase in access to clean water, sanitation, and electricity from an Infrastructure Push, relative to the Current Path.

Access to information communication technology (ICT) is also enhanced in this Push, though most of the investment is from the private sector. These interventions—whether public or private—would also target mobile broadband and fixed broadband access. Such an investment would likely catalyze smart phone penetration, potentially increasing access rapidly enough that one could imagine a context in which all African mobile phones are smart within 15 years. Fixed broadband should increase as well—by as much as 9 percentage points by 2038 relative to the Current Path.

These investments do cost money, and the pay-off period for such an Infrastructure Push would span as long as 20 years. The cost-benefit curve below explores this by measuring the total investment needed (above the Current Path) to achieve such an Infrastructure Push across time, compared with the absolute annual change in overall GDP.

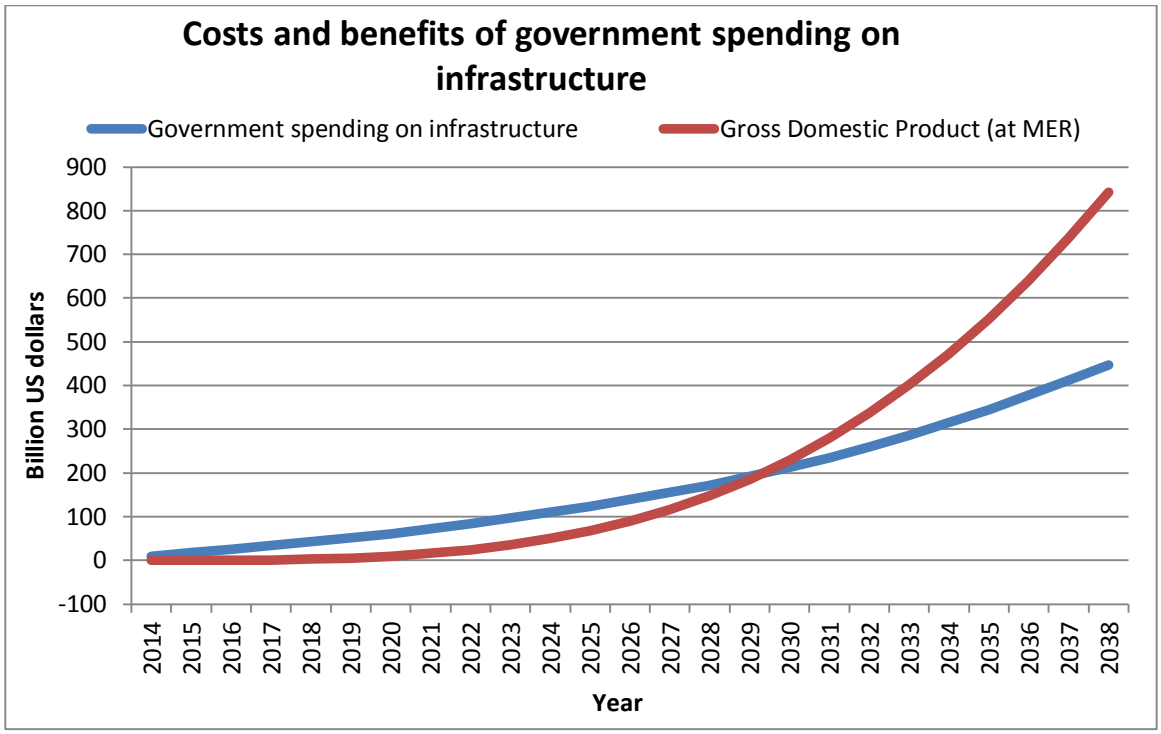


Figure 15: Cost and benefits of an Infrastructure Push relative to the Current Path.

Besides the enormous effects the Infrastructure Push might have in communications, transportation, and electricity access, Africans could also expect to see positive impacts elsewhere. Since this strategy would initially divert funds away from health and education spending, it's unlikely that the Infrastructure Push would lead to a significant net increase in HDI over time. Nevertheless, improvements in infrastructure could lead to a reduction in extreme poverty by as much as 40 percent and increase GDP by more than 4 percent by 2038.

Integrated Policy Analysis: Integrated Push

The previous sections outlined realizable expectations around large-scale, continental policy interventions that emphasize agriculture, education, governance, health, and infrastructure. Each Push demonstrated a reasonable way for Africans to continue to encourage human development, reduce extreme poverty, and improve African production significantly over the next 50 years.

But what happens if Africa combined each of these interventions? If they are each achievable in isolation, what happens if similar efforts are brought together? This section will present an Integrated Push for Africa that brings together interventions in each of the sectors above.

With bold, reasonable interventions across all sectors, an Integrated Push might offer Africans the prospect of real transformational growth that would exceed that of the Current Path or any other individual Push.

The comparison done in this section needs a caveat, however. The different interventions explored above were each calibrated to be within historically reasonable levels, but it is virtually impossible to

compare the size of one Push against another. For example, is a 2-percentage-point increase in educational enrollment rates similar to a 2-percentage-point improvement in governance effectiveness? Not directly in a quantifiable way, at least. In addition, not all of the strategic policy and investment decisions are modeled (or can be modeled).

Understanding the comparison below to be a stylized, continent-level overview of the impact of different policy interventions is important.

> If Africa pursued the Integrated Push with reasonable interventions in all areas, GDP could nearly double in comparison to the Current Path.

The Integrated Push would require governments to make more concessions among various sectors or issue areas. For example, since other sectors demand resources in an integrated scenario, education spending is not as high as it was in the Education Push. In the same way, the infrastructure roll out is slightly more limited than in the Infrastructure Push, etc. Despite these trade-offs in initial spending, bold, reasonable interventions across all sectors, an Integrated Push might offer Africans the prospect of real transformational growth that would exceed that of the Current Path or any other individual Push.

When reviewing the following graphs in this section, please consider an important caveat: each alternative Push produces different, yet still positive results. For example, health greatly improves HDI but has less an impact on extreme poverty; infrastructure improves GDP but does little to improve HDI, and so on. Policymakers at the national or regional level must be cautious about taking these graphs and applying any interpretations universally to their country. Instead, this forecast is meant to point to analytical capability applied at the continental level that could also be applied at the regional or national level. Any individual country or regional analysis would produce different results.

Figure 16 demonstrates the behavior of each Push along with the Integrated Push as it relates to poverty reduction on the continent. Agricultural Push has the greatest initial impact on reducing the number living in extreme poverty. This is largely a product of the simulated policy of increasing food access to the poorest on the continent. Long term, however, the Governance Push and the Health Push would likely achieve greater reductions in extreme poverty. Even so, if the continent pushed aggressively and simultaneously in all major systems, those living in extreme poverty could be reduced by more than 95 percent relative to the Current Path.

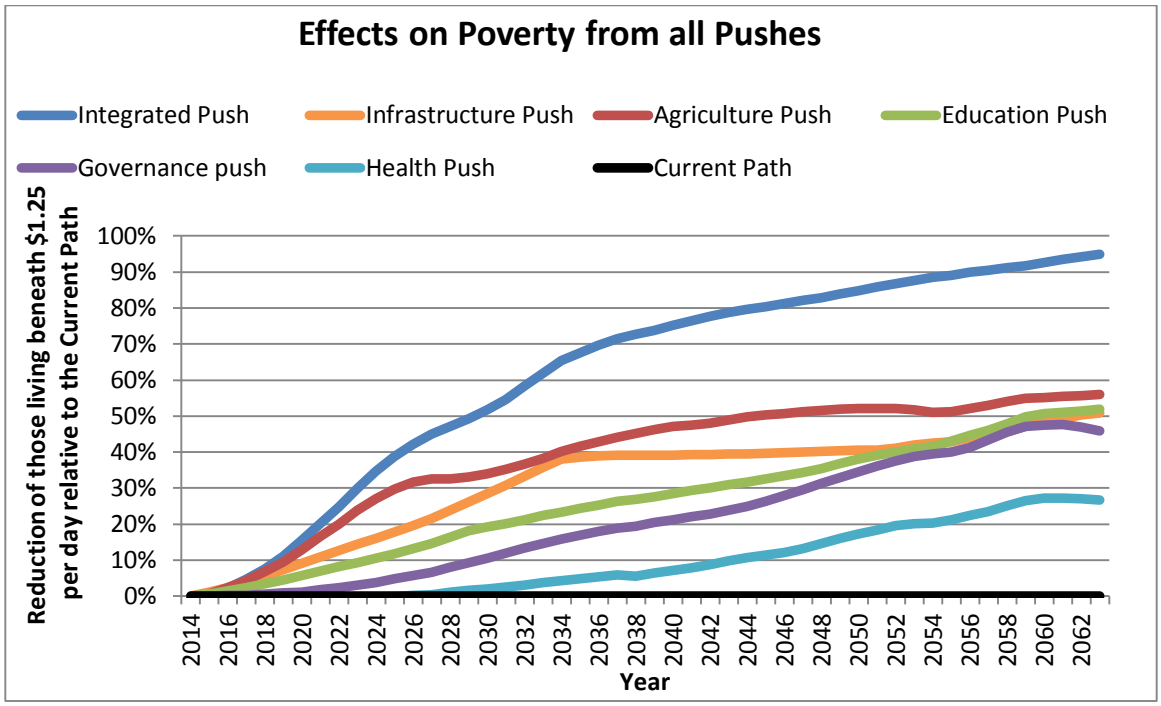


Figure 16: The percent reduction in people living in extreme poverty, relative to the Current Path, across each major Push

In terms of the HDI, shown in Figure 17, big improvements could come from all sectors at different points over the time horizon. A Health Push would improve life expectancy significantly, but continued improvements would become more challenging. Similarly, an Education Push might improve the number of years people go to school and the expected years of education, but again this trend would begin to plateau relative to the Current Path as greater percentages of the population access more education. According to our forecasts, both the Governance Push and Infrastructure Push would appear to have long-term, positive spillover impacts on the HDI, while an Agriculture Push would have an initially positive impact on HDI that may eventually dip below the Current Path by the end of the time horizon.

Yet, if the continent pushed on each of these policy interventions simultaneously—as in the Integrated Push—the continent's HDI could plausibly increase by close to 13 percent.

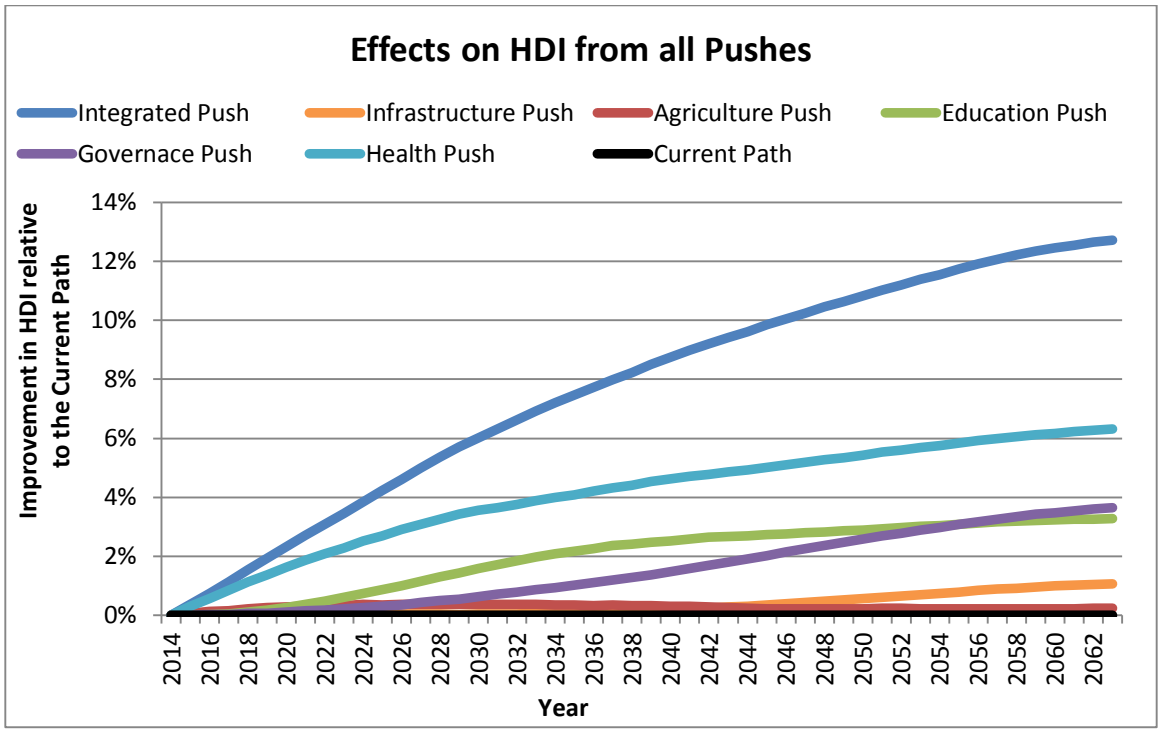


Figure 17: Percent improvement in the Human Development Index, relative to the Current Path, across each major Push.

Lastly, the impact of each Push, including the Integrated Push, is shown on overall GDP. Figure 18 displays the results. Among the five policy-area pushes, one could expect the biggest returns through improvements in governance. Current levels of governance indeed have room for considerable improvement, which might then lead to improvements in social productivity. Additionally, extra attention to infrastructure might encourage large overall increases in GDP output. While such interventions would appear to bring about large gains in overall GDP, others show net-negative, or near-net-negative impacts. The Agriculture Push, for example, draws capital from other sectors that would have likely produced higher value-added prospects, and therefore it could decrease overall production in the long run.

Conversely, if Africa pursued the Integrated Push with reasonable interventions in all areas, GDP could nearly double in comparison to the Current Path.

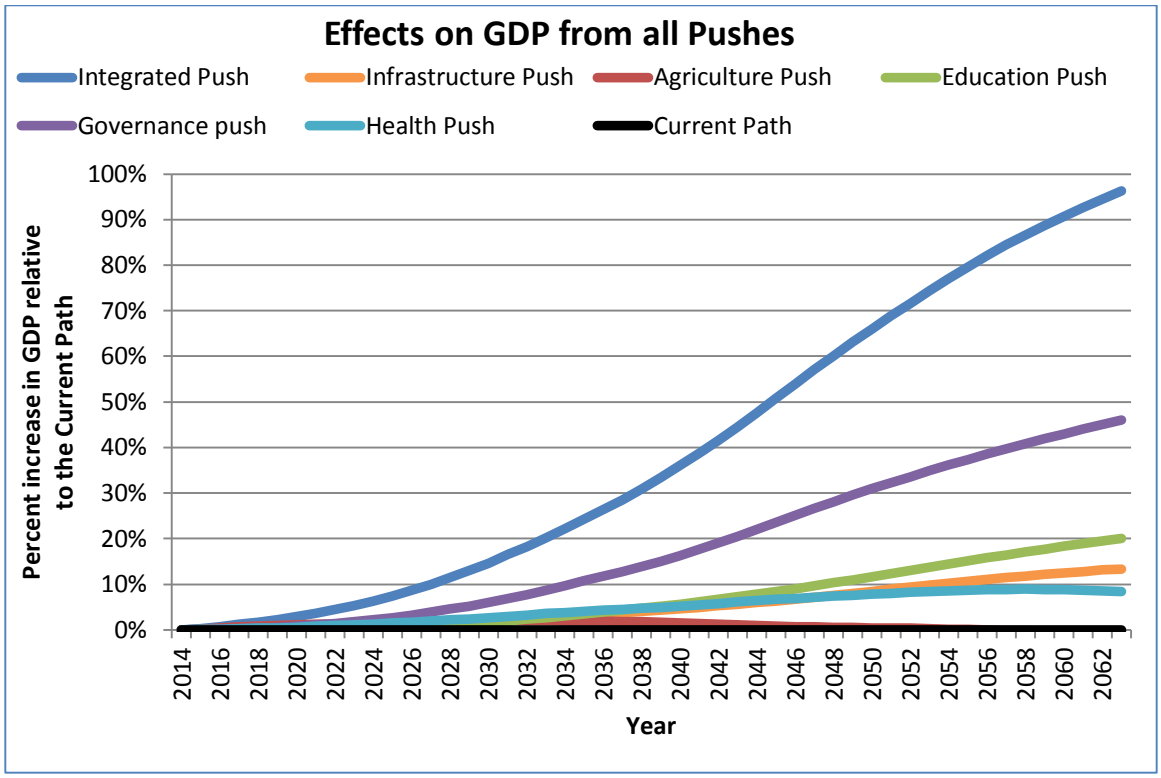


Figure 18: Percent increase in GDP, relative to the Current Path, across each major Push.

While the Integrated Push does improve African development considerably in all three measures, additional trade-offs should be considered. Because of the increased continental economic output, carbon emissions could grow by 30 percent for Africa by the end of the time horizon relative to the Current Path. This would lead to slightly more intense climate change (an increase of global temperature of 0.1 degrees relative to the Current Path). Moreover, even with the Integrated Push, there will still be 11.8 million people living in extreme poverty in 2063. And because overall demand for resources is higher, there will be a substantial increase in the real price of food and energy, making life even more challenging for those living in the most dire developmental situations.

Conclusion

On the Current Path, the future of Africa is bright. But it can be even more brilliant. NEPAD can play a pivotal role in accelerating that process.

As these forecasts show, Africa has many reasons to be optimistic as it moves along the Current Path of development. With collective action towards common goals, the continent should expect human development to expand, infrastructure to strengthen, agriculture to improve, and governance to mature. Moving forward, however, there are important concerns that must also be addressed. Climate change will continue to impact African lives; extreme poverty remains a burden; and too many Africans lack access to basic human services.

This report highlights one way that African can plan for more effective development. Leadership in Africa must think critically and in an integrated fashion across development issue areas, as well as across political boundaries and time. This report is a call for integrated thinking across all aspects of African development planning.

Building from this, NEPAD endeavors to be a key technical body for the implementation of the Agenda 2063 activities. The organization already has begun the process of setting targets through our emphasis on agriculture (CAADP) and infrastructure (PIDA). NEPAD has also been active in developing strategies across other issue areas as well. The NEPAD agency seeks to extend these targets across issue areas as well as tailor them for specific development at continental, regional and country levels.

However, more analysis needs to be accomplished with key stakeholders. It will take time and commitment to establish a series of sound targets reflecting the vast quantity of variables across policy areas. To do this requires further enhancement our modelling capabilities and evidence-based monitoring and evaluation capacities across the continental, regional, and national levels.

The future of Africa is bright, but, with effective leadership, it could be more brilliant. The NEPAD agency can play a pivotal role in accelerating that process. All relevant stakeholders in the Agenda 2063 process should embrace this integrated policy analysis approach as a means to technically evaluate the development potential of all of its members.

Appendix 1: Description of Scenario Interventions for "Push" Interventions

Agriculture							
	Agricultural Demand Multiplier (Crops) (agdemm)				Increase to 1.75 over 50 yrs		Multiplies values of demand of certain foods
	Agricultural Demand Multiplier (Meat) (agdemm)				Increase to 1.75 over 50 yrs		
	Agricultural Investment Multiplier (aginvm)				Increase to 1.50 over 50 yrs		Multiplies value of investment in agriculture.
	Domestic Gini Multiplier (ginidomm)				Decrease to 0.75 over 20 yrs		Multiplies value of Gini Coefficient (0 = equal wealth distribution, 1 = unequal wealth distribution)
Land	Target Growth in Cultivated Land (tgrld)				0.08		Sets value (as decimal) of annual growth of cultivated land (e.g. a value of .01 means annual growth of 1%). This value is set in initial year.
Yield	Agricultural Yields Multiplier (ylm)				Increase to 2.0 over 50 yrs		Multiplies agriculture yields
	Maximum Possible Agricultural Yields (Tons/Hectare)						Sets a maximum level of yield for land. In this case, specific values have been applied to each country.
	Algeria	10.7	Somalia	8	Mozambique	9.6	
	Egypt	14.9	Sudan	11.4	Namibia	14.2	
	Libya	9.8	Tanzania	7.7	South Africa	5.9	
	Mauritania	10.1	Uganda	6.5	Swaziland	4.2	
	Tunisia	10.3	Angola	7.1	Zambia	9.1	
	Burundi	5.3	Botswana	13.1	Zimbabwe	9.1	
	Djibouti	9	Comoros	9.6	Cameroon	6.1	
	Eritrea	10.4	Lesotho	4.8	Central African Republic	7.4	
	Ethiopia	8.1	Madagascar	8.4	Dem. Rep. of Congo	4.9	

	Kenya	12.9	Malawi	9.1	Republic of Congo	6.1
	Rwanda	7.6	Mauritius	9.6	Equatorial Guinea	4.2
	Gabon	4.9	Mali	12	Guinea	7.2
	Sao Tome and Principe	6.1	Niger	14.5	Guinea Bissau	7.9
	Chad	13	Senegal	11.2	Liberia	5
	Burkina Faso	9.5	Benin	8.1	Nigeria	7.9
	Cape Verde	12.6	Cote d'Ivoire	5.6	Sierra Leon	5.3
	Gambia	10	Ghana	6.6	Togo	6.5

Education			
	Domestic Gini Multiplier (ginidomm)	Decrease to 0.9 over 20 yrs	Multiplies value of Gini Coefficient (0 = equal wealth distribution, 1 = unequal wealth distribution)
Primary	Net Intake Annual Growth Rate (edpriintngr)	2.5	Sets rate (as a %) of student intake (e.g. a value of 1.0 means annual growth of 1%). Primary Net intake rate is calculated by dividing the total school-age student body by the offical school-age population. A country's net intake should not exceed 100%.
	Survival Annual Growth Rate (edprisurgr)	2.5	Sets rate (as a %) of student survival (e.g. a value of 1.0 means annual growth of 1%). A country's survival rate indicates how many students are retained each grade.
	Gender Parity Time for Intake (edprigndregintn)	10	Gender parities for intake and survival rates are set to equal 1.0 after 10 years. A gender parity value of 1.0 is an equal ratio among females and males.
	Gender Parity Time for Survival (edprigndreqsur)	10	
	Primary Education Expenditure per Student as % of gdppc convergence time to function (edexppconv)	16	Sets the number of years a country's expenditure as % of gdppc (gross domestic product per capita) will converge to the expected value.
Lower Secondary	General Transition Annual Growth Rate (edseclowrtrangr)	2.5	Transition rates from primary to lower secondary are set to increase 0.85% every year. Transition rates indicate how many students enter lower secondary after completing primary.

	Survival Annual Growth Rate (edseclowrsurvgr)	2.5	Sets rate (as a %) of student survival (e.g. a value of 1.0 means annual growth of 1%). A country's survival rate indicates how many students are retained each grade.
	Gender Parity Time for Transition (edseclowrgndreqtran)	1.5	Years until transition and survival rates reach gender parity.
	Gender Parity Time for Survival (edseclowrgndreqsurv)	1.5	
	Lower Secondary Education Expenditure per Student as % of gdppc convergence time to function (edexpslconv)	16	Sets the number of years a country's expenditure as % of gdppc (gross domestic product per capita) will converge to the expected value.
Upper Secondary	General Transition Annual Growth Rate (edsecupprtrangr)	2.0	Transition rates from lower to upper secondary are set to increase 0.5% every year.
	Survival Annual Growth Rate (edsecupprsurvgr)	2.5	Sets rate (as a %) of student survival (e.g. a value of 1.0 means annual growth of 1%). A country's survival rate indicates how many students are retained each grade.
	Gender Parity Time for Transition (edsecupprgndreqtran)	10	Years until transition and survival rates reach gender parity.
	Gender Parity Time for Survival (edsecupprgndreqsurv)	10	
	Upper Secondary Education Expenditure per Student as % of gdppc convergence time to function (edexpsuconv)	16	Sets the number of years a country's expenditure as % of gdppc (gross domestic product per capita) will converge to the expected value.
Tertiary	General Intake Annual Growth Rate (edterintgr)	2.5	Sets rate (as a %) of student survival (e.g. a value of 1.0 means annual growth of 1%). A country's survival rate indicates how many students are retained each grade.
	Graduation Annual Growth Rate (edtergradgr)	2.0	Indicates an annual 0.5% increase in students who graduate tertiary education.
	Gender Parity Time for Intake (edtergndreqint)	1.5	Years until intake and graduation rates will reach gender parity.
	Gender Parity Time for Graduation (edtergndreqgrad)	1.5	

	Lower Secondary Education Expenditure per Student as % of gdppc convergence time to function (edexptconv)	16	Sets the number of years a country's expenditure as % of gdppc (gross domestic product per capita) will converge to the expected value.

Governance			
Capacity	Export Shift as Result of Promotion of Exports - Ratio (xshift)	0.04	Increases exports of materials, manufactured goods, and services. Changes are offset by changes in private and government consumption
	Government Expenditures by Destination Multiplier (Military) (gdsm)	Decrease to 0.8 over 25 yrs (starting in 2014)	Multiplies military expenditures by set value.
	Government Expenditures by Destination Multiplier (Other) (gdsm)	Decrease to 0.8 over 25 yrs (starting in 2014)	Multiplies other government expenditures by set value.
	Government to Household Welfare Transfers Multiplier (Unskilled) (govhhtrnwelm)	Increase to 2.0 over 25 yrs (starting in 2014)	Multiplies government transfers to social welfare
	Government Revenues Multiplier (govrevm)	Increase to 1.2 over 16 yrs (starting in 2014)	Multiplies government revenue
	Government Corruption Measure Standard Error Target (govcorruptsetar)	1	Government corruption value set to reach 1 standard deviation from expected within 25 years.
	Years to Target Government Corruption Standard Error (govcorruptseyrtar)	25	
	Government Regulatory Quality Standard Error Target (govregqualsetar)	1	Government regulatory quality value set to reach 1 standard deviation from expected within 25 years.
	Years to Target Government Regulatory Quality Standard Error (govregqualseyrtar)	25	
	Government Effectiveness Measure Standard Error Target (goveffectsetar)	1	Government effectiveness measure set to reach 1 standard deviation from expected within 25 years.
	Years to Target Government Effectiveness Measure Standard Error (goveffectseyrtar)	25	
Inclusion	Female labour force multiplier (labfemshrm)	Increase to 1.5 over 50 yrs (starting in	Multiplies female share of the labour force

		2014)	
	Gender Empowerment Measure Standard Error Target (gemsetar)	1	Gender empowerment measure set to reach 1 standard deviation within 25 years.
	Years to Target Gender Empowerment Measure Standard Error (gemseyrtar)	25	
	Economic Freedom Multiplier (econfreem)	Increase to 1.20 over 25 yrs (starting in 2014)	Multiplies countries' values associated with economic and political freedom.
	Freedom (political) Multiplier (freedomm)	Increase to 1.2 over 25 yrs (starting in 2014)	
	Polity Democracy Index Standard Error Target (democpolitysetar)	1	Polity Democracy index is set to reach 1 standard deviation from expected value within 40 years.
	Years to Target Polity Democracy Index Standard Error (democpolityserstar)	40	
Security	State Failure/internal war, addition probability (sfintlwaradd)	0 to -0.5 over 30 yrs (starting in 2014)	Probability of state failure from internal conflict is gradually decreased.

Health			
Communicable Disease	AIDS death rate as % of HIV infection rate multiplier (aidsdratem)	1 to 0.4 over 15 yrs (starting in 2015)	Multiplies the rate of AIDs death as % of HIV infection rate
	Residential PM2.5 levels multiplier (envpm25hldsw)	1 to 0.3 over 25 yrs (starting in 2015)	Multiplies air quality as measure by amount of ultrafine particles (2.5 micrometers in diameter and smaller).
	Malnutrition Multiplier (malnm)	1 to 0.5 over 25 yrs (starting in 2015)	Multiplies the Prevalence of child malnutrition
	Total Fertility Rate Multiplier (tfrm)	1 to 0.7 over 75 yrs (starting in 2015)	Multiplies Total Fertility Rate.
Injuries	Vehicle Fleet Per Capita Multiplier (vehicflpcm)	1 to 0.5 over 25 yrs (starting in 2015)	Multiplies the vehicle fleet per capita rate.

	Deaths from Traffic per Vehicle Multiplier (deathstrpvm)	1 to 0.5 over 25 yrs (starting in 2015)	Multiplies deaths from traffic accidents per vehicle.
Non Communicable Disease	BMI Multiplier (hlbmim)	1 to 0.9 over 25 yrs (starting in 2015)	Multiplies the body mass index of populations
	Smoking Rate Multiplier (hlsmokingm)	1 to 0.7 over 25 yrs (starting in 2015)	Multiplies each country's rate of smoking population.

Infrastructure			
	Domestic Gini Multiplier (ginidomm)	Decrease to 0.9 over 20 yrs	Multiplies value of Gini Coefficient (0 = equal wealth distribution, 1 = unequal wealth distribution)
Energy	Electricity Access Standard Error Target (efraelecaccsetar)	2	Standard error target and years after for population percentage with access to electricity
	Year to Target Electricity Access Standard Error (efraelecaccseyrtar)	40	
	Electricity Transmission Loss Multiplier (infraelectranlossm)	1 to 0.5 over 10 yrs (starting in 2015)	Multiplier on the loss of electricity in transmission and distribution
	Solid Fuel Use Standard Error Target (ensolfuelsetar)	-2	Standard error target and years after for target achievement for percentage of households reliant on solid fuels
	Years to Solid Fuel Use Standard Error (ensolfuelseyrtar)	40	
ICT	Fixed Broadband Standard Error Target (ictbroadsetar)	2	Standard error target and years after for target achievement for fixed broadband access
	Years Target Fixed Broadband Standard Error (ictbroadseyrtar)	20	
	Mobile Broadband Standard Error Target (ictbroadmobilsetar)	2	Standard error target and years after for target achievement for ICT mobile broadband access
	Years to Target Mobile Broadband Standard Error (ictbroadmobilseyrtar)	40	
Roads	Rural Road Access Standard Error Target (infraroadsaisetar)	0.2	Standard error target and years after for target achievement for rural road access
	Years to Target Rural Road Access Standard Error (infraroadsaiseyrtar)	40	

Water Sanitation	Wastewater Standard Error Target (watwastetreatsetar)	2	Standard error target and years after for target achievement for wastewater access
	Years to Target Wastewater Standard Error (watwastetreatseyrtar)	40	
	Safe Water No Connection Standard Error Target (watsafehhconsetar)	-2	Standard error target and years after for target achievement for safe water access
	Years to Target Safe Water No Connection Standard Error (watsafehhconseyrtar)	40	
	Sanitation No Connection Standard Error Target (sanitnoconsetar)	-2	Standard error target and years after for target achievement for sanitation access
	Years to Target Sanitation No Connection Standard Error (sanitnoconseyrtar)	40	

Appendix 2: Some Technical Documentation on International Futures

The International Futures (IFs) system is complex. To ensure transparency, much has been done to make the model assumptions and structure open. The actual model can be used online or downloaded from Frederick S Pardee Center for International Futures webpage for free (www.ifs.du.edu/ifs). The online Help System (www.du.edu/ifs/help) is a rich repository of information on the model. Visit this site for information on model structure for each sub-system:
http://www.du.edu/ifs/help/understand/index.html

The following text is a re-print from an appendix to the following article:

> Hughes, Barry B., Mohammod T. Irfan, Jonathan D. Moyer, Dale S. Rothman, and José R. Solórzano. "Exploring Future Impacts of Environmental Constraints on Human Development." *Sustainability* 4, no. 5 (May 10, 2012): 958–980. doi:10.3390/su4050958.

Each of the models within the IFs system is very large, generally comparable in character and structure to the most substantial models in their respective issue areas at institutions such as the United Nations Population Division (population forecasting), the World Bank (economic forecasting), the International Institute for Applied Systems Analysis (education forecasting), the World Health Organization (health forecasting), and so on. We therefore must be selective here with respect to documentation.

The model structure is recursive (sequential computation of each equation in every annual time step) rather than relying upon simultaneous or iterative within-year solution procedures. Much attention is paid to maintaining accounting identities, including (1) those around global production, consumption, and trade of food categories (crops and meat) and of energy types (oil, natural gas, coal, hydropower, nuclear power, and new renewables), both in physical and value terms; and (2) those involving inter-sectoral flows and inter-agent (households, firms, and governments) flows nationally and internationally, in value terms. Because the model's orientation is long-term forecasting, it is also important that it track stocks (accumulations such as the growth of atmospheric carbon and the decline of fossil fuel resource bases) as well as annual flows; yet the model structure is not systems dynamics in form, but rather a hybrid involving also many econometrically estimated specifications. Further, its long-term character and its integration of multiple issue areas means that specifications of algorithmic structures (such as endogenization of multifactor productivity driven by human, social, physical, and natural capital elements) can become as important as equations. All of this is to explain that the equations below are only a part of the overall system.

Sequencing of equations for recursive solution frequently involves moving out of one major model (e.g., population) into another (e.g., economics) and then later back again to earlier models. The sequencing is actually somewhat different in the first year of the model's computation, when many variables are initialized, than in all subsequent years. Prior to the first or base year of computation (currently 2010) the system relies on an extensive "pre-processor" of data for all its models, reconciling (again often with algorithms) physical and value estimates that are often incompatible and filling holes in data for the

system's 186 countries (often using cross-sectional formulations tied to income levels). We focus here, however, only on the annual computations for years after the initialization.

Notation explanation. n the equations that follow we show variable names (explained in the text) in capital letters and parameters in lower case. We use bold face to represent values exogenous to the system, namely initial conditions of variables (from data) or parameters. The subscript "r" refers to geographic region, which in IFs is almost always a country (the model now represents 186 countries). Second subscripts represent additional dimensionality (s for economic sector, f for food type, e for energy type, g for government spending sector). The superscript "t" refers to the current time step; "t-1" to a variable computed in a previous time step and carried forward; and "t=1" to initial conditions.

Population and Economic foundations. The first calculations are of basic variables in what are essentially the two core models of the IFs system (see again Figure 1 of the article). In the demographic model we draw heavily upon the age-sex population distributions and other variables computed at the end of the previous time step to compute population (simply a sum across the age distribution), population growth, median age, HIV rate, AIDs deaths, calorie demands, sub-populations of importance (e.g., the size of the working-age population), and household-size. In the economic model, again using variables from previous years that we will explain below, we compute, inter alia, labour supply, female share of labour, exogenous technological growth, human capital, social capital, physical capital, knowledge capital, and productivity growth.

Agriculture. We then use such basic variables as important drivers for demand and supply sides in the physical models of the system, namely agriculture and energy, as well as a few infrastructure variables that we omit here because of more substantial treatment later (in interaction with variables in each of these models that also carry over from past years). Turning first to agricultural production, crop and meat/fish supply have very different bases and IFs determines them in separate procedures. Crop production depends on yields per hectare of land under cultivation and on the amount of land cultivated. Yield functions are almost invariably some kind of saturating exponential which represents decreasing marginal returns on inputs such as fertilizer or farm machinery. IFs also uses a saturating exponential, but imposes it on a Cobb-Douglas form. The Cobb-Douglas function is used in part to maintain symmetry with the economic submodel but more fundamentally to introduce labour as a factor of production along with capital. Especially in less developed countries (LDCs) where a rural labour surplus exists, there is little question that labour, and especially labour efficiency improvement, can be an important production factor. "Know-how" is also important in agriculture and there is therefore a technology term.

IFs computes yield in two stages. The first provides a basic yield (BYL) representing change in long-term factors such as capital and labour. The second stage uses this basic yield as an input and modifies it based on prices and therefore on the representation over time of the supply-demand equilibrium.

The basic yield (BYL) requires capital in agriculture (KAG), labour (LABS), technological advance (AGTECH), a scaling parameter (CD), and an exponent (CDALF). In addition a saturation coefficient (SATK)

introduces the behavior of the saturating exponential. Interpret AGTECH as a factor-neutral technological progress coefficient.

$$BYL_r = CD_r * (1 + AGTECH_r)^{t-1} * KAG_r^{CDALF_{r,s=1}} * LABS_{r,s=1}^{(1-CDALF_{r,s=1})} * SATK_r$$

where

$$CD_r = \frac{\boldsymbol{YL}_r^{t=1}}{\boldsymbol{KAG}_r^{t=1(\boldsymbol{CDAAG}_r)} * \boldsymbol{LABS}_{r,s=1}^{t=1 \quad (1-\boldsymbol{CDAAG}_r)}}$$

$$AGTECH_r = AGTECH_r^{t-1} * \left(1 + TECHGRO_{r,s=1}\right)$$

The saturation coefficient is a multiplier of the Cobb-Douglas function. It is the ratio of the gap between an exogenously specified maximum possible yield and the most recently computed yield to the gap between the maximum yield and the initial yield, raised to an exogenous yield exponent. With positive parameters the form produces decreasing marginal returns.

The basic yield represents the long-term tendency in yield but, because agricultural production levels are quite responsive to short–term factors such as fertilizer use levels and intensity of cultivation, the annual yield will vary significantly around that tendency. Those short-term factors under farmer control (therefore excluding weather) depend in turn on prices, or more specifically on the profit (FPROFITR) that the farmer expects. Because of computational sequence, we use food stocks as a proxy for profit level and adjust basic yield accordingly.

There are, however, additional factors that can influence agricultural yield. The one of importance to us here is global climate change. IFs therefore recomputes yield (YL), modifying it by two multipliers. The first summarizes the impact on yield of changes in precipitation and temperature resulting from global levels of atmospheric carbon (ENVYLCHG); we lag that variable from the previous time step and will see its computation near the end of this appendix. The second factor is a regional yield multiplier (ylm) that allows the model user to introduce assumptions about weather patterns and other uncertain elements in the agricultural system.

$$YL_r = BYL_r * \left(1 + ENVYLCHG_r^{t-1}\right) * \boldsymbol{ylm}_r$$

Finally, agricultural production (AGP) in the first or crop category is the product of yield and land devoted to crops (LD).

$$AGP_{r,f=1} = YL_r * LD_{r,l=1}$$

The production of fish has two components, ocean and mariculture. Total global ocean fish catch (OFSCTH) is set exogenously, as is each region's share in it (RFSSH) and the regional value of aquaculture (AQUACUL). Livestock production (AGPLV) is dependent on the herd size (LVHERD) and the slaughter rate (SLR). Total fish and livestock production, food category two, is the sum. Some food production will never make it to markets, but will be lost in the field or in distribution systems to pests, spoilage, *etc*. That loss (LOSS) is a function of GDP per capita in a table function that captures the tendency of loss to decrease with higher income levels. A loss multiplier (LOSSM) allows
scenario introduction.

Energy. Basic total energy demand (BENDEM) for a given region or country is tied very closely to gross domestic product (GDP). IFs actually uses GDP from a previous time cycle (with an estimate of growth) because the recursive structure of IFs computes current GDP later.

The units of energy required for every unit of gross domestic product (ENDK) are a function of GDP per capita in purchasing power terms (GDPPCP), computed in a table function.

$$ENDK_r = \textbf{\textit{TablFunc}}(GDPPCP_r)$$

Initial data from countries/regions are unlikely to fall exactly on this table function initially. To reconcile computed energy demand (ENDEM) in the first year with empirical demand, IFs computes an internal adjustment multiplier (ENDM),which relies in turn on energy demand the first year; initial energy demand is apparent consumption computed from the sum across types of energy production (ENP) plus imports (ENM) minus exports (ENX).

$$BENDEM_r = GDP_r^{t-1} * (1 + GDPR_r^{t=1}) * ENDK_r * ENDM_r$$

where

$$ENDM_r = \frac{ENDEM_r^{t=1}}{GDP_r^{t=1} * \textbf{\textit{ENDK}}_r^{t=1}}$$

$$ENDEM_r^{t=1} = \sum^{E} \textbf{\textit{ENP}}_{r,e}^{t=1} + \textbf{\textit{ENM}}_r^{t=1} - \textbf{\textit{ENX}}_r^{t=1}$$

Final energy demand (ENDEM) is a price-responsive function of this basic energy demand. Possible tax on the consumer's price added by carbon taxes (cartaxenpriadd) is added to the basic market price. In an earlier version of the submodel, we used a smoothed or moving-average, regionally-specific energy price (SENPRI) relative to the initial price value (ENPRI). Because energy is a quite highly integrated global market, and in order to enhance behavioral stability, we have gone to using the world energy price (lagged one year) relative to initial price; prices affect demand through an elasticity (elasde). The user can force change in energy demand directly via an energy demand multiplier (endemm).

$$ENDEM_r = BENDEM_r * \left(1 + \frac{\textbf{\textit{cartaxenpriadd}}_{r\,r} + WEP^{t-1} - \textbf{\textit{ENPRI}}_r^{t=1}}{\textbf{\textit{ENPRI}}_r^{t=1}} * \textbf{\textit{elasde}}_r\right) * \textbf{\textit{endemm}}_r$$

The basic computation of energy production (ENP) uses only capital as a factor or production. Energy production is the quotient of capital in each energy category (KEN) and the appropriate capital-to-output ratio (QE). The model user can modify a multiplier to this ratio (QEM) to represent changes in technology. The capital-to-output ratio is itself a function of resource availability. Known reserves (RESER) pose a direct constraint on production; they are constrained by ultimate resource assumptions in an important process not described here. The reserve-to-production ratio may not fall below a specified factor (PRODTF). In the case of oil and gas, for example, no more than about 10% of known reserves can be produced in a given year. Within the reserve constraint, the user can force increases or decreases in production via an energy production multiplier (ENPM). A capacity utilization factor (CPUTF) also affects the production level and is computed dynamically over time to help maintain market equilibrium (as are prices).

$$ENP_{r,e} = MIN\begin{cases} \dfrac{KEN_{r,e}}{QE_{r,e} * \boldsymbol{qem}_{e}} * \boldsymbol{enpm}_{r,e} * CPUTF_{r} \\ \dfrac{RESER_{r,e}}{\boldsymbol{prodtf}_{r,e}} * CPUTF_{r} \end{cases}$$

Return to the Economic Model and Production. The physical flows of the partial equilibrium models for energy and agriculture, along with the change over time in relative prices for those goods (computed in processes that equilibrate the global market but also represent changing production cost fundamentals), provide inputs to two of the six sectors in the economic model (those six being agriculture, energy, other raw materials, manufactures, energy, and information and communications technology). They can therefore next be integrated with more value-based computations for the other sectors in the important production side of the economic model.

A Cobb-Douglas function produces value added (VADD) as a function of capital (KS) and labour (LABS), a cumulative technological growth factor (TEF), and a scaling parameter (CDA) computed in the first time step. The capital exponent CDALFS) and its labour complement are endogenous, and the capital share declines with GDP per capita [1].

$$VADD_{r,s} = CDA_{r,s} * TEF_{r,s} * KS_{r,s}^{\boldsymbol{CDALFS}_{r,s}} * LABS_{r,s}^{(1-CDALFS_{r,s})}$$

where

$$TEF_{r,s} = TEF_{r,s}^{t-1} * \left(1 + MFPGRO_{r,s}\right)$$

The annual growth rate in multifactor productivity (MFPGRO) requires, of course, further explanation. As discussed above, there is a base rate (MPRATE) linked to systemic technology advance and a convergence premium. Specifically, the base rate sums the exogenously specified rate of advance in the leader (mfpleadr) and the premium computed for convergence of each country/region (MFPPrem), a function of GDP per capita at purchasing power parity (GDPPCP).

$$MFPGRO_{r,s} = MFPRATE_{r,s}$$
$$+ HumanCapitalTerm_{r,s} + SocialCapitalTerm_{r,s}$$
$$+ PhsyicalCapitalTerm_{r,s} + KnowledgeTerm_{r,s}$$
$$+ MFPCOR_{r,s}$$

where

$$MFPRATE_{r,s} = \boldsymbol{mfpleadr}_s + MFPPrem_r$$

where

$$MFPPrem_r = Func(GDPPCP_r)$$

On top of the base rate, multiple (currently four) terms additively affect/shift growth over time, each comparing country performance with structural expectations [2]. The model computes an adjustment or correction factor (MFPCOR) in the first year so as to make the overall growth rate initially consistent with recent historical experience for the country.

Turning to the four clusters of drivers discussed above, we discuss the human capital term illustratively. The annual change in MFP attributable to education (CNGEDUC) is the sum of two terms. The first compares the endogenous computation of average years of education (EDYRSAG25) of the population at age 25 or older (responsive to all of the factors represented in the education module) minus the expected value of the same variable computed from a cross-sectional function (EXPECTEDEDYRSAG25). The second term similarly compares the portion of the GDP that government directs to education (g=EDUC) with the expected value of the same ratio. The contribution to the human capital from health is directly comparable. Four parameters from the literature (in bold face) convert differences from expected values into shifts of productivity growth.

$$HumanCapitalTerm_{r,s} = CNTEDUC_r + CNGHLTH_r$$
$$CNGEDUC_r = (EDYRSAG25_r - EXPECTEDYRSAG25_r) * \boldsymbol{mfpedyrs}$$
$$+ \left(\frac{GDS_{r,g=EDUC}}{GDP_r} - Expected \frac{GDS_{r,g=EDUC}}{GDP_r} \right) * \boldsymbol{mfpedspn}$$
$$CNGHLTH_r = (LIFEXP_r - ExpectedLIFEXP_r) * \boldsymbol{mfplife}$$
$$+ \left(\frac{GDS_{r,g=Health}}{GDP_r} - Exppected \frac{GDS_{r,g=Health}}{GDP_r} \right) * \boldsymbol{mfphlspn}$$

Often across the IFs system, it's necessary to estimate parameters from the database of over 2,000 series across the multiple issue areas. But in many critical areas, especially those in which there are large literatures, we draw from those literatures so as to incorporate expertise that ranges far beyond our own. Hughes [3] described the parameterization of the production system, drawn from an extensive literature of estimations and stylized facts on productivity [4]. Illustratively, parameterization considered years of education and educational expenditures as a pair. Analyses in the literature include:

Barro and Sala-i-Martin [5] reported that a 1 standard deviation increase in male secondary education raised economic growth by 1.1% per year, and a 1 standard deviation increase in male higher education raised it by 0.5%. Barro [6] reported that one extra year of male upper-level education raised growth by 1.2% per year.

Chen and Dahlman [7] concluded that a rise of 20% in average years of schooling raises annual growth by 0.15 percent and that an increase in average years by 1 year raises growth by 0.11 percent.

Jamison, Lau, and Wang [8] used the Barro-Lee measure of average years of school for males between 15 and 60, but concluded that the "effect was small".

Bosworth and Collins [9] argued that each year of additional education adds about 0.3% to annual growth.

The OECD [10] found that one additional year of education (about a 10% rise in human capital) raised GDP/capita in the long run by 4–7%.

Barro and Sala-i-Martin [5] concluded that increasing education spending as a portion of GDP by 1.5 points (one standard deviation) raised growth by 0.3%.

Baldacci, Clements, Gupta, and Cui [11] found that raising education spending in developing countries by 1% a year and keeping it higher added about 0.5% per year to growth rates. They also found that 2/3 of the effect of higher spending is felt within 54 years but the full impact shows up only over 10–15 years.

Gross regional or domestic product (GDP) is simply the sum of value added across sectors, which would also equal the sum of production for final demand across sectors. And the GDP per capita (GDPPC) follows easily.

The basic GDP figures for the model are represented in dollars at official exchange rate values. It is important, however, to estimate the value of GDP and GDPPC at purchasing power parity levels as well (GDPP and GDPPCP). To do that we need to compute a purchasing power parity conversion value (PPPConV). Data sources provide the initial conversion value. IFs uses an analytic function based on GDP per capita to compute change in the conversion value over time.

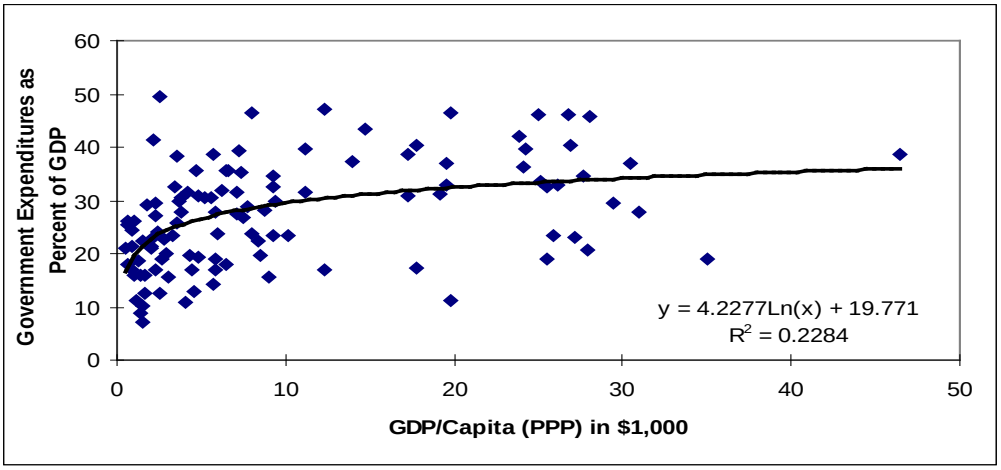
$$GDPP_r = GDP_r * PPPConV_r$$
$$GDPPCP_r = GDPPC_r * PPPConV_r$$
$$where$$
$$PPPConV_r = PPConV_r^{t=1} * \frac{AnalFunc(GDPPC_r)}{AnalFunc(GDPPC_r^{t=1})}$$

Broader Financial Flows and the Social Accounting Matrix. The computational flow moves next to financial flows, beginning with computations of assorted international flows, including foreign direct investment (maintaining stocks over time as well as flows), portfolio investment, IMF and World Bank

credits and loans, and worker remittances. As in many areas of the model, we do not, of course, expect to be able to forecast these with any reasonable accuracy for 186 countries over the long run. But they are important variables for which we can provide basic relationships, thereby also adding handles for users undertaking scenario analysis.

Turning to the domestic side of financial flows, and beginning with expenditures, Figure A.1 shows the function estimated cross-sectionally in order to fill the relatively few holes in government expenditures as a portion of GDP (using data from the World Development Indicators).

Figure A.1. Government Expenditure Share as Function of GDP/capita (PPP).



Government expenditures consist of a combination of direct consumption/expenditure and transfer payments. As a general rule, transfer payments grow with GDP per capita more rapidly than does consumption. And within transfer payments, pension payments are growing especially rapidly in many countries, particularly in more-economically developed ones.

In future years the total of government expenditures is calculated from the sum of direct consumption and transfers. The two components, however, each require a moderately complex calculation that we do not elabourate here. Computation of government consumption (direct expenditures on the military, education, health, R&D, foreign aid, and other categories) begins with use of the function to compute an estimated government consumption (EstGovtConsum) as a portion of GDP, using GDP per capita (PPP) as the driver. The initialization discussion above showed the empirical base of that function. It carries a behavioral assumption of generally increasing expenditures with increases in GDP per capita.

The estimated value then enters a convergence calculation that IFs uses in a number of instances. In the first year a ratio term (GovConR) was computed that represented the degree to which a country's consumption/GDP differed from the estimated value. That ratio multiplies the estimated term in future years, allowing the function normally to increase consumption/GDP as GDP per capita rises. At the same time, such divergence from estimated functions is almost as often a matter of data inadequacy or of temporary factors for a country as it is of persistent idiosyncrasy. The convergence function allows the country/region's value to converge towards the functional calculation over a period of time

(govfinconv), usually quite long. Such convergence also helps avoid ceiling effects (e.g., government consumption as 100% of GDP) as GDP per capita rises.

The second term in the equation below is called the Wagner term, after the discoverer of the long-term behavioral tendency for government consumption to rise as a share of GDP, even at stabile levels of GDP per capita. This is built into the consumption calculation through an exogenous parameter (wagnerc) that is multiplied by the number of the forecast year.

$$GOVCON_r = Converge(EstGovtConsum_r * GovConR_r^{t=1}, EstGovtConsum_r, \boldsymbol{govfinconv})$$
$$* WagnerTerm * \boldsymbol{govexpm}_r * MulExp_r^{t-1}$$
$$where$$
$$WagnerTerm = 1 + t * \boldsymbol{wagnerc}$$
$$EstGovtConsum_r = AnalFunc(GDPPCP_r^{t=1})$$

Almost finally, government consumption is further modified by an exogenous multiplier of government expenditures, allowing the user to directly control it by country/region and by an endogenously computed multiplier on expenditures (MulExp) that reflects the balance or imbalance in government expenditures and the debt level. Finally, and not shown, there is a simple adjustment to reflect the effect that changing levels of foreign assistance receipts can have on consumption.

The division of government expenditures into target destination categories (GDS) is, of course, also a key agent-class behavior. We do not describe it in detail here, but it involves determining demand for military, health, education, R&D, infrastructure and a residual other category of expenditures from extended representations of the demand for all but R&D and the residual other category. Actual expenditures are normalized to total government consumption.

Governance. The IFs system represents a number of governance variables in the general categories of security, capacity, and inclusion. Here we illustrate just two. With respect to capacity, one of the most powerful measures of capacity (or more accurately, lack of capacity) may well be corruption. We rely in our analysis on the Transparency International measure of corruption perceptions, which in spite of the name they give it is actually a measure of transparency (higher values are more transparent or less corrupt). Note that the basic formulation in IFs for corruption/transparency (below) contains four drivers, all of which are significant, and which collectively explain nearly 80 percent of the cross-country variation in corruption in the most recent year of data for each variable. The first term, and the one that by itself explains the most variation, is a long-term development term, in this case GDP per capita (for some variables to be discussed below, such as democracy, that development variable is years of education).

Interestingly another very powerful term is the UNDP Gender Empowerment Measure (GEM), which, in spite of its high correlation with GDP per capita, makes its own contribution. A secondary term is the

extent of democracy using the Polity scale (DEMOC). That this term makes an independent contribution to transparency suggests the power that inclusion may have to increase accountability and transparency, reducing corruption. An even-less-powerful but still-significant term is the dependence of the country on exports of energy (ENX) converted to value terms with prices (ENPRI)—in a few years, and in the aftermath of the Arab Spring beginning in 2011, it will be interesting to know if this term drops out of analyses of change in governance regime and character. A multiplier for scenario analysis is the only exogenous element added to the basic formulation (govcorruptm). This equation has an R-squared in 2010 of 0.76.

$$GOVCORRUPT_r^t = (1.576 + 0.1133 * GDPPCP_r^t + 2.270 * GEM_r^t + 0.02779 * DEMOC_r^t - 0.04566 * (\mathrm{ENX}_r^t * \mathrm{ENPRI}_r^t / \mathrm{GDP}_r^t)) * \boldsymbol{govcorruptm}_r^t$$

With respect to inclusion, we pay particular attention to regime type. As with capacity, the forecasting of regime type in IFs has multiple elements: (1) a basic statistical formulation tied to literature analysis and our own estimations; (2) a recognition of country-specific differences (tied in part to path dependencies); and (3) an algorithmic specification of a number of additional factors, including global waves and neighborhood effects.

Most analyses of democratization place much emphasis on a developmental variable such as GDP per capita. GDP per capita and adults' years of education are very highly correlated across countries, and we found that, although the correlation of GDP per capita and democracy level is slightly higher than that of education years and democracy, when we added the size of the youth bulge and the extent of dependence on energy exports, the better broad developmental driving variable proved to be years of adults' education. With additional exploration, however, we found a slight further advantage for the Gender Empowerment Measure, and so replaced the education variable with the GEM (which is, itself, strongly influenced by adults' education). In the equation below, the basic IFs formulation, all terms are significant with T-scores above 2.0 in absolute terms. In earlier work we also explored a linkage to the survival/self-expression dimension of the World Value Survey, but have found that other development variables statistically force it out of the relationship.

$$DEMOC_r^t = 13.39 + 11.37 * GEM_r^t - 9.734 * YTHBULGE_r^t - 0.2317 * (\mathrm{ENX}_r^t * \mathrm{ENPRI}_r^t / \mathrm{GDP}_r^t)) * \boldsymbol{democm}_r^t$$

IFs has the capability of doing an historical simulation between 1960 and 2010 so that we can compare our forecasts with data. Our forthcoming governance volume [12] documents our use of that in order to build a broader forecasting structure on top of the basic equation above, as well as documenting the rest of the governance model. Governance variables enter the economic model primarily via the production function described above.

Agricultural Demand. Sequentially it could have been computed earlier (many of the IFs sequential steps could be changed), but agricultural demand is dependent on estimates of income. Crop demand has three components: feed, industrial and food. These equations are important but do not greatly affect the dynamics that surround analysis in this article, so we do not document them here.

Back to the Economy: But looking forward with investment. The determination of investment by destination that will carry changes in capital stock to the next time period is a two-step procedure. First, IFs computes demand for investment by each sector (IFSDEM), responsive primarily to inventory (or stock) levels. This is a reasonably extensive process involving the use of what engineers term a PID controller to feed back information from inventories (the integral of disequilibrium and annual change of inventories (the derivative term in PID) to the demand for investment funds.

More generally, a variety of PID controller mechanisms help the model in the chasing of equilibrium over time. These mechanisms show up in all price calculations (food and energy prices in the physical models and relative prices of all other sectors in the economic model), in determinations of interest rates for balancing savings and investments, and in determininations of exchange rates for relative currency values. It is typical to talk of alternative "closures" in describing economic models, that is the use of hard specification of supply or demand side variables to determine equilibrium. Our more open method of search for it with signals back to the supply and demand sides allows both exogenous interventions on both sides (related to the kinds of scenario specifications described in the article) and more elabourate specifications of both supply and demand sides, including the multiple linkages across models that this appendix has been describing.

Building Infrastructure. Here we compute many infrastructure demand and access variables including Road Density, Paved Roads, Rural Roads Access Index, Cost of adding a lane km of paved road, Land Area Equipped for Irrigation, Per Hectare Cost of equipping land for irrigation, Fixed Telephone Line density, Cost of adding a fixed land line, Access to Electricity Grid, Electricity Consumption, Electricity Transmission Loss, Electricity Generation Capacity, Electricity Generation Capacity Cost, Computers per 100 people, Access to Sanitation facilities, Cost of Sanitation, Access to Safe Water, Cost of Safe Water. We illustrate this with only one, electricity access.

$$INFRAELECACC_{urban} = \frac{100}{1 + e^{-(1.144 - 4.858 * poverty\ level + 0.837 * GOVEFFECT)}}$$

$$INFRAELECACC_{rural} = \frac{100}{1 + e^{-(-0.500 - 6.925 * poverty\ level + 0.858 * GOVEFFECT)}}$$

where

INFRAELECACC is the percentage of the urban or rural population with access to electricity, poverty level is the fraction of the total population that lives on less than $1.25 per day, and GOVEFFECT is a measure of governance effectiveness developed as part of the World Bank's World Governance Indicators project.

We recognize that there is a strong connection between the use of electricity and of solid fuels in the home. In general, as households move up the energy ladder, they increase their use of the former and decrease their use of the latter. We also include a link from access to electricity to the use of solid fuels in the home. This in turn enters the health model and affects the level of respiratory disease.

International Political Variables. We next compute a number of international political variables, including a power measure based on hard capabilities and an estimate of intra-dyadic threat. Those are not of great relevance to this article, so we do not elaborate them.

Population Dynamics. We are in a position at this point to compute a number of variables relevant to the dynamics of population over time. Although births, deaths, and migration all influence population dynamics, the most influential of the three is births. We therefore focus here on the critical variable, total fertility rate (TFR). IFs determines the TFR and then imposes that on the fertility distribution of the region/country.

Infant mortality (INFMOR), years of average education for those 15 and older (EDYRSAG15), and contraception use (CONTRUSE) are key drivers of fertility rates. In addition there is an exogenous multiplier on the rate (tfrm), and shift in that function with technological or cultural change (ttfrr).

$$TFR_r = (3.8812 + 0.0217 * INFMOR_r - 0.8327 * \ln(EDYRAG15_r) - 0.0095 * CONTRUSE_r) * \boldsymbol{tfrm}_r * (1 + (t-1) * \boldsymbol{ttfrr})$$

Total fertility rate is, however, unlikely to shift indefinitely toward zero. In fact, it requires a value of about 2.0 simply to maintain a steady population (unless life expectancies are growing). TFR is therefore bound by a minimum that responds to a global parameter (tfrmin) normally set at either 1.5 or 1.8.

Once we have computed the total fertility rate (TFR), the number of births in a given year is a simple function of the fertility distribution and the TFR. On the mortality side, mortality patterns determine life expectancy and affect the progression of each age category through time. IFs includes an entire health model, based on work from the Global Burden of Disease project of the World Health Organization, but we do not need to document that here. We also compute other demographic variables of importance at this point including contraceptive use, births, deaths, infant mortality, crude birth rate, crude death rate, calories per capita, and malnourished children.

Other Human Development Variables. At this point we turn to the education model of IFs and compute expenditures per student, gross enrollment demand, graduates per level, years of education for people over 25 and for people over 15, and literacy.

Having computed economic, health, and education variables, we are able to compute also the Human Development Index (HDI) in the standard equation of the United Nations Human Development Report Office.

Other Variables, Indicators, and Forward Linkages. At this stage there are further calls to many of the models in IFs, some of them repeatedly, in order to calculate a wide range of variables that carry over to the next time step and of indicators of interest to model users. These include health variables such as smoking prevalence; smoking impact; BMI; obesity; mortality by country, age, gender and disease type; life expectancy; deaths per disease type; infant mortality; crude death rate; population growth rate; years of life lost; and years lost to disability. They also include: income-related variables such as household income per capita, domestic Gini, population living with income under $1.25/day and $2/day,

poverty gap, household savings, firm savings, and global Gini; environmental variables such as urban pollution measured with PM2.5 levels, annual carbon emissions from fossil fuels, advanced sustainability analysis, precipitation change, temperature change, and agricultural yield change; agricultural variables such as return ratio on land/yield investment, investment in agriculture, urban built-up land development, crop land development, and grazing land development; knowledge system variables such as knowledge system index, knowledge human capital index, knowledge ICT index, knowledge innovation index, and knowledge international transfer index.

To illustrate some of special importance to this article, consider carbon emissions and the stock of atmospheric carbon. The beginning point for examining the greenhouse effect is calculation of the atmospheric carbon dioxide in parts per million (C02PPM). The model calculates annual emissions of carbon from energy use (CARANN) and adds it to a cumulative tracking of carbon (SACARB), initialized exogenously for 2010 (carint). Emissions depend on global production (WENP) in the fossil fuel categories (oil, gas and coal), using fuel-specific coefficients representing tons of carbon generated per barrel of oil equivalent burned (carfuel). The oceans and other sinks annually absorb an exogenously specified amount of atmospheric carbon (carabr) and that retards the accumulation. Deforestation (or reforestation) has an impact via another parameter (carforst).

$$CARANN = WENP_{e=1} * \textbf{carfuel1} + WENP_{e=2} * \textbf{carfuel2} + WENP_{e=3} * \textbf{carfuel3}$$

$$SACARB = SACARB^{t-1} + CARANN + (WFORST^{t-1} - WFORST) * \textbf{carforst} - \textbf{carabr}$$

where

$$SACARB^{t=1} = \textbf{carinit}$$

We use a table function (based on figures from the IPCC) to determine the average world temperature (WTEMP) in Centigrade from the atmospheric carbon dioxide level in parts per million.

$$WTEMP = TablFunc(CO2PPM)$$

Given forecasts of global temperature change over time we are able to compute temperature and precipitation changes post 1990 for each country (TEMPCHG and PRECHG) using data compiled for the MAGICC/SCENGEN climate model [13]. Building on work by Cline [14] and Rosenzweig and Igelesias [15] we then estimate a variable that combines the effects of those variables with carbon fertilization into a multiplier on agricultural yield resulting from environment (ENVYLCHG). We saw earlier the impact of this on yields

Conclusion. As we indicated at the beginning of this appendix, the IFs modelling system is a compilation of many very large individual models. As a result, it is impossible to provide full detail here. We have tried, instead, to indicate the key equations related to this article, the overall dynamics of annual computations, the roots of the system in an extensive database, and the widespread reliance on the expertise of others to structure the models, their equations and our parameterization. We welcome inquiries for more information.

References and Notes

1. Estimation of the relationship for capital share uses Global Trade and Analysis Project (GTAP) data, as do a number of other aspects of the model. For instance, the input-output matrices and factor.

2. Not shown, there is also an exogenous additive parameter (mfpadd) allowing users to intervene and change growth paths for any country/region. The presentation of equations here omits a number of such "exogenous handle" parameters and terms not central to the exposition.

3. Hughes, B.B. Productivity in IFs. Pardee Center for International Futures, University of Denver, Denver, CO, USA, 2005. Available online: http://www.ifs.du.edu/documents/reports.aspx (accessed on 7 May 2012).

4. Mankiw, Romer and Weil (1992) was one of the early extensive empirical analyses of growth. They found that the Solow model was generally correct and useful, but that a CES formulation improved performance. We stay here with the Cobb-Douglas version because it is so widely used. They also found that human capital accumulation, which they tapped with secondary school enrollment was very important and that OECD countries behaved differently than low income ones.

5. Barro, R.; Sala-i-Martin, X. *Economic Growth*; MIT Press: Ipswich, MA, USA, 1999; p. 431.

6. Barro, R.J. Inequality, Growth, and Investment; NBER Working Paper No. w7038; National Bureau of Economic Research, Cambridge, MA, USA, 1999, pp. 19–20. Available online: http://ssrn.com/abstract=156688 (accessed on 9 May 2012).

7. Chen, D.H.C.; Dahlman, C.J. Knowledge and Development: A Cross-Section Approach. World Bank Policy Research Working Paper No. 3366, World Bank, Washington, DC, USA, 2004; Available online: http:// papers.ssrn.com/sol3/papers.cfm?abstract_id=616107 (accessed on 9 May 2012).

8. Jamison, D.; Lau, L.; Wang, J. Health's Contribution to Economic Growth in an Environment of Partially Endogenous Technical Progress. In *Health and Economic Growth: Findings and Policy Implications*; Lopez-Casanovas, G., Rivera, B., Currais, L., Eds.; MIT Press: Cambridge, MA, USA, 2005; p. 82.

9. Bosworth, B.P.; Collins, S.M. The empirics of growth: An update. Brookings Papers on Economic Activity, 2003, p.17. Available online: http:// www.brookings.edu/~/media/Files/rc/papers/2003/0922globaleconomics_bosworth/20030307.pdf (accessed on 9 May 2012).

10. Organisation for Economic Co-operation and Development (OECD). *The Sources of Economic Growth*; OECD: Paris, France, 2003; pp. 76–78.

11. Baldacci, E.; Clements, B.; Gupta, S.; Cui, Q. Social Spending, Human Capital, and Growth in Developing Countries: Implications for Achieving the MDGs. IMF Working Paper 04/217, International Monetary Fund, Washington, DC, USA, 2004; p. 24.

12. Hughes, B.; Joshi, D.; Moyer, J.; Sisk, T.; Solórzano, J. *Strengthening Global Governance*; Paradigm Publishers: Boulder, CO, USA; Oxford University Press: New Delhi, India, 2013, in press.

13. Wigley, T.M.L. *MAGICC/SCENGEN 5.3: User Manual (version 2)*; National Center for Atmospheric Research: Boulder, CO, USA, 2008. Available online: http://www.cgd.ucar.edu/cas/wigley/magicc/UserMan5.3.v2.pdf (accessed on 7 May 2012).

14. Cline, W.; *Global Warming and Agriculture: Impact Estimates by Country*; Peterson Institute for International Economics: Washington, DC, USA, 2007.

15. Rosenzweig, C.; Iglesias, A. *Potential Impacts of Climate Change on World Food Supply: Data Sets from a Major Crop Modeling Study*; Columbia University, Center for International Earth Science Information Network: New York, NY, USA, 2006.

Bibliography

African Union. *Africa Health Strategy 2007-2015: Index.* Draft document. Prepared for the Third Session of the African Union Conference of Ministers of Health (South Africa: Johannesburg 2007).

African Union. *Second Decade of Education for Africa (2006-2015).* Plan of Action (Addis Ababa, Ethiopia: AU 2006).

Barry B. Hughes and Evan E. Hillebrand, *Exploring and Shaping International Futures* (Boulder, CO: Paradigm Publishers, 2006).

Barry B. Hughes, *Development-Oriented Policies and Alternative Human Development Paths*, Paper, United Nations Development Programmeme (UNDP) (New York, NY: UNDP Human Development Report Office, 2013).

Barry B. Hughes, Devin Joshi, Jonathan D. Moyer, Timothy Sisk, José Solorzano, *Patterns of Potential Human Progress: Strengthening Governance Globally* (Boulder, CO: Paradigm Publishers, forthcoming).

Barry B. Hughes, Jonathan D. Moyer and Timothy D. Sisk, *Vulnerability to Intrastate Conflict: Evaluating Quantitative Measures*, Paper, United States Institute of Peace (Washington, D.C.: United States Institute of Peace, 2011).

Barry B. Hughes, Mohammod Irfan, Haider Khan, Krishna Kumar, Dale S. Rothman, and José R. Solórzano. *Patterns of Potential Human Progress: Reducing Global Poverty* (Boulder, CO: Paradigm Publishers, 2011).

Barry B. Hughes, Randall Kuhn, Cecilia M. Peterson, Dale S. Rothman and Jose R. Solorzano, *Patterns of Potential Human Progress: Improving Global Health* (Boulder, CO: Paradigm Publishers, 2011).

Barry B. Hughes, Randall Kuhn, Cecilia M. Peterson, Dale S. Rothman, José R. Solórzano, Colin D. Mathers, and Janet R Dickson. Projections of global health outcomes from 2005 to 2060 using the International Futures integrated forecasting model. *Bulletin of the World Health Organization*. 89 (7): 469-544. 2011.

CAADP. *The Comprehensive Africa Agriculture Development Programmeme (CAADP).* CAADP website, accessed October 8th, 2013.

Dale S. Rothman, Mohammod T. Ifran, Eli Margolese-Malin, Barry B. Hughes and Jonathan D. Moyer, *Patterns of Potential Human Progress: Building Global Infrastructure* (Boulder, CO: Paradigm Publishers, 2013).

Ibrahim Assane Mayaki. B*olstering Regional Infrastructure in Africa Through the Implementation of PIDA*. Prepared for United Nations, New York, 15 October 2012.

Jakkie Cilliers and Hanna Camp, *Highway or Byway? The National Development Plan 2030*, Brief, Institute for Security Studies (ISS) and the Frederick S. Pardee Center for International Futures (Pretoria, South Africa: Institute for Security Studies, 2013).

Jakkie Cilliers and Julia Schunemann, *The future of intrastate conflict in Africa: More violence or greater peace?*, Paper, Institute for Security Studies (Pretoria, South Africa: Institute for Security Studies, 2013).

Jakkie Cilliers, Barry Hughes and Jonathan Moyer, *African Futures 2050: The next forty years*, Mongraph, Institute for Security Studies (ISS) and the Frederick S. Pardee Center for International Futures (Pretoria, South Africa : Institute for Security Studies, 2011).

Jakkie Cilliers and Timothy D. Sisk. *Prospects for Africa's 26 Fragile Countries.* Institute for Security Studies (Pretoria, South Africa : Institute for Security Studies, 2013).

Janet R. Dickson, Barry B. Hughes and Mohammod T. Ifran, *Patterns of Potential Human Progress: Advancing Global Education* (Boulder, CO: Paradigm Publishers, 2010).

Jonathan D Moyer and Eric Firnhaber, *Cultivating the Future: Exploring the Potential and Impact of a Green Revolution in Africa*, Brief, Intitute for Security Studies (ISS) and the Frederick S. Pardee Center for International Futures (Pretoria, South Africa: Intitute for Security Studies, 2012).

Jonathan D. Moyer and Graham Emde, *Malaria No More: Expectation for Eradication*, Brief, Insitute for Security Studies (ISS) and the Frederick S. Pardee Center for International Futures (Pretoria, South Africa: Insitute for Security Studies, 2012).

Keith Gehring, Mohammod Ifran, Patrick McLennan, Jonathan D. Moyer, Hopolang Selebalo and Erin Torkelson, *Knowlege Empowers Africa: The Benefits of Increased Investment in Education*, Brief, Institute for Security Studies (ISS) and the Frederick S. Pardee Center for International Futures (Pretoria, South Africa: Institute for Security Studies, 2011).

Mark Eshbaugh, Eric Firnhaber, Patrick McLennan, Jonathan D. Moyer and Erin Torkelson, *Taps and Toilets: How Greater Access Can Radically Improve Africa's Future*, Brief, Institute for Security Studies (ISS) and the Frederick S. Pardee Center for International Futures (Pretoria, South Africa: Institute for Security Studies, 2011).

Mark Eshbaugh, Greg Maly, Jonathan D Moyer and Erin Torkelson, *Putting the Brakes on Road Traffic Fatalities in Africa*, Brief, Institute for Security Studies (ISS) and the Frederick S. Pardee Center for International Futures (Pretoria, South Africa: Institute for Security Studies, 2012).

Mohammod T. Ifran and Eli Magolese-Malin, *SADC Higher Education Futures 2050*, Report, SARUA Leadership Dialogue Series Volume 3, Number 2, Southern African Regional Universities Association (South Africa: SARUA, 2012).

Mohammod T. Ifran, *Forecasting Educational Achievement Relative to Millennium Development Goals: Inadequacy of Financial Interventions in the Contexts of Under-capacity, Under-efficiency and Under-participation.* Paper, University of Denver (2005)

NEPAD. *African Peer Review Mechanism (APRM)*. NEPAD website, accessed October 10th, 2013.

NEPAD. *The AU/NEPAD Capacity Development Strategic Framework (CDSF).* Framework document (Addis Ababa, Ethiopia: NEPAD 2009).

UN Economic Commission for Africa. *The Development State: What Options for Africa?* Prepared for the third Meeting of the Committee on Governance and Popular Participation. 20-21 February 2013 (Addis Ababa, Ethiopia: UNECA 2012).