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MALARIA NO MORE: EXPECTATIONS FOR ERADICATION

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SUMMARY

This policy brief explores the possible impact should Africa eliminate malarial infection by 2025. Between 2015 and 2050, when comparing the International Futures Base Case with a Malaria Eradication scenario (explained below), the continent could experience the following benefits:

- **Eliminate 12 million deaths from malaria, with the greatest absolute reduction in Nigeria and the Democratic Republic of the Congo (DRC)**
- **Add more than 50 million years of healthy life**
- **Increase overall economic output – by nearly US$ 430 billion largely due to increases in production**
- **Increase per capita income for Africans by more than US$ 30 per person in 2050**
- **Prevent nearly 2,5 million people from living on less than US$ 1,25 per day in 2050.**

MALARIA AND HUMAN DEVELOPMENT

Malaria killed approximately 940 000 Africans in 2010.[1] Of the 25 countries in the world with the highest death rates from malaria, 24 are African. In the Base Case of the International Futures (IFs) system, we expect deaths to decrease at an annual rate of 3 to 4 per cent over the next decades as current efforts to combat the disease continue to impact upon its spread.[2]

The reason why Africa has the largest number of malaria cases is that the most effective transmitter of malaria, the mosquito species *Anopheles gambiae*, is only found in Africa, and it has developed resistance to some insecticides.[3] In addition, the dominant form of malaria in Africa is the most dangerous species, *Plasmodium falciparum*,[4] and it has developed resistance to some antimalarial drugs.[5]

Malaria disproportionately impacts small children and infants, with children under five accounting for 90 per cent of malaria-induced deaths.[6] Young children are the biggest at-risk group because their immune systems are not strong enough to resist the disease. Infections in adults, on the other hand, do not usually result in death since adults living in malaria-endemic regions develop immunity through repeated exposure to the disease.

In high-risk areas, people are bitten by infected mosquitoes about 40 to 100 times a year and suffer malarial episodes once or twice a year. During an episode of malaria, victims are completely incapacitated for four to six days and seriously weakened for two weeks. Symptoms include fever, headache, nausea, diarrhoea, delirium, and jaundice.[7]

Poverty and malaria have an undeniable relationship. All of the ten countries with the highest malaria death rates had over 40 per cent of their populations living on less

than US$ 1,25 per day in 2010. The 31 richest countries in the world are all malaria-free, and the poorest country in the western hemisphere, Haiti, also has the highest rate of malaria deaths in the region.[8] Ecology and climate are the main drivers of the disease. Malaria thrives near standing water, where mosquitoes can breed, and in tropical temperatures, which aid in the incubation of the parasite.[9] McCarthy, Wolf, and Wu point out that average temperature, average rainfall, and proximity to the equator are important environmental drivers of malaria's incidence, but they conclude that the location of a country does not predestine it to suffer from the disease.[10]

Although poverty does not cause malaria, malaria does increase poverty. Malaria most often impacts the poor, and the economic costs of malaria can push poor households deeper into poverty.[11] Several macroeconomic studies have shown that malaria has a measurable impact on overall economic performance. In their 1998 study, Gallup and Sachs, for example, calculated that a 10 per cent reduction in malaria corresponded to a 0,3 per cent increase in gross domestic product.[12]

Sachs's later study with Warner in 2001 calculated that countries struggling with severe malaria also suffered from constrained GDP growth rates of approximately 1 per cent a year, a seemingly small difference but one that compounds impressively across time.[13] According to the economics models used at the Copenhagen Consensus, achieving the Millennium Development Goal of reducing the malaria burden by 50 per cent between 2002 and 2015 would have corresponded to an annual benefit of US$ 3 to 10 billion to the global economy.[14]

Malaria negatively affects economies because it reduces productivity. Barofsky et al wrote that if an expecting mother contracts malaria it can stunt childhood development even before birth.[15] This subsequently has a detrimental effect on school attendance and then on productivity in later years. The authors estimated that the 1959 – 1960 programme led by the World Health Organization (WHO) to eliminate malaria in Kigesi, Uganda, resulted in an extra 0,3 years of education for those born in the region after eradication – an increase which corresponds to a 2,9 per cent average annual increase in income per person.[16]

Despite the apparent link between malaria and poverty, many scholars have rejected the notion that malaria eradication would produce economic benefits. In the 1950s, when the WHO began its original Global Eradication Campaign, several economists voiced their concern that eliminating malaria would not have significant economic benefits. For example, Pletsch and Chen presented a study to the WHO in 1954 stating that eradicating malaria in Taiwan would have little economic benefit to the country. They pointed to the problem of overpopulation and argued that Taiwan already had a surplus of labour.[17] In 1967, Barlow's economic model supported this analysis, showing that malaria elimination would be unlikely to have an effect on per capita income in Sri Lanka in the long run, owing to strong population growth in the country.[18]

Some contemporary scholars have also questioned the value of switching from a policy of controlling malaria to a policy of eradication. Sabot et al concluded that it is unlikely that moving toward a policy of eradication would be cost effective over a 50-year period.[19] Packard went one step further by calling into question the work of Sachs and others, and highlighting the general lack of evidence that authors have to support their claims of large forward impacts from reducing malaria prevalence.[20] One concern about malaria eradication is the possibility of rapid population growth. Malthusian pessimists argue that rapid population growth in poor countries can exacerbate existing problems.[21] Neo-classical economists counter that rapid population growth may in fact lead to increased labour competition, driving up production and innovation.[22]

Yet, malaria eradication may not lead to rapid population growth. Malaria primarily takes the lives of infants, and eradication could have positive impacts on fertility trends. Yamada explained that declines in infant mortality trigger declines in fertility rates.[23] Two things happen to produce the change: first, women spend more time in the post-partum state of infertility while they breastfeed their living children;[24] and, second, parents stop having children sooner because they reach their desired number of children faster.[25] In areas with high infant mortality rates, parents cannot reach their desired number of children without having more children to compensate for those who have died or who they fear might die.[26] That said, declines in fertility do slightly lag behind declines in infant mortality because it takes time for people to adjust their reproductive habits.[27]

MALARIA PREVENTION AND THE SEARCH FOR A CURE: PAST AND PRESENT

Malaria has been with humans for at least 50 000 years, and the particularly dangerous species, *Plasmodium falciparum*, has been afflicting Africa for the past 6 000 years.[28] Only at the end of the 1800s did people discover that mosquitoes transmitted malaria, and only in the 1920s did drug companies produce chloroquine, the first successful antimalarial drug.[29]

In the 1930s, scientists discovered the insecticidal properties of DDT. After World War II the international community began to discuss the possibility of eradicating malaria. Armed with chloroquine and DDT, the newly formed WHO championed the cause of global malaria eradication when it launched its Global Malaria Eradication Campaign in 1955. The campaign achieved some success, eradicating the disease in 37 countries and reducing it in many others.[30] Most of this success was in the developed world, however, and many antimalarial programmes in developing countries lacked sufficient support to eliminate the disease completely. Particularly in Africa the disease persisted, and in 1969 the WHO admitted that the campaign for global eradication had failed and the organisation abandoned its goal of malaria eradication.[31]

Throughout the remainder of the 20th century, the WHO focused on malaria control rather than eradication. Unfortunately, many of the gains made by the Global Eradication Campaign were reversed during this period. Donor fatigue, the parasite's growing resistance to antimalarials, and mosquitoes' growing resistance to insecticides were the primary causes of this reversal. The 1990s saw a resurgence of the disease, even in countries that had once seen the disease nearly eradicated.

In 2001 Kofi Annan, the then-UN Secretary General, called for a new campaign to eradicate malaria. Bill and Melinda Gates echoed this in October 2007,[32] and their efforts to fight malaria have helped to inspire a new campaign to eradicate the disease. Because of the generous donations of the Gates Foundation and those it has inspired, malaria now receives approximately ten times more funding than it did at the turn of the century.

The WHO immediately responded to the calls for malaria eradication by publishing two documents – *Malaria Elimination: a Field Manual for Low and Moderate Endemic Countries and Global Malaria Control and Elimination*. These documents reestablished the WHO's commitment to malaria eradication programmes and reasserted its dedication to malaria control. By pursuing both control and elimination, the WHO plans to continue with the control programmes that have been successful over the past decade, while exploiting recent developments in science for the production of new and more effective antimalarial drugs.

Today the fight against malaria is largely a partnership between the public and private sectors. In 2001, Annan called on the international community to create an independent organisation dedicated to the funding of the treatment and prevention of HIV/AIDS, tuberculosis, and malaria. Shortly thereafter, the international community cooperated to create the Global Fund to Fight AIDS, Tuberculosis and Malaria, which receives donations from countries and private donors such as the Bill and Melinda Gates Foundation.[33] The Gates Foundation donates more than any other private organisation to development causes in Africa, and its malaria division, the Gates Malaria Partnership (GMP), has a two-pronged approach: (1) building capacity for treatment and vector control; and (2) supporting a research infrastructure for African scientists with the goal of developing an effective vaccine.[34]

Building capacity for vector control has focused on insecticide-treated mosquito nets (ITNs) and indoor residual spraying (IRS). ITNs are bed nets designed to keep mosquitoes away during the night when people are most vulnerable to being bitten. ITNs are also an important strategy in the fight against malaria because their continued and widespread use breaks the cycle of infection; mosquitoes are less likely to carry the disease and infect others when they cannot bite infected people.[35] Public and private donors helped to distribute more than 294 million ITNs across Africa between 2008 and 2010, a total that represents a potential 73 per cent coverage of the continent's at-risk population.[36] By 2010, 35 per cent of young African children used ITNs, which is a vast improvement but still far from WHO's goal of 80 per cent coverage.[37] IRS is another method of controlling mosquito populations. WHO estimates that IRS protected 10 per cent of at-risk Africans in 2010, while in some countries, such as Equatorial Guinea, São Tomé and Príncipe, and South Africa, IRS protected about 80 per cent of the population.[38]

While control of mosquito populations can have an enormous impact on malaria, the hope for eradication rests primarily on the development of an effective antimalarial vaccine. Dozens of malaria vaccines have been in devel-

opment since the 1990s, but none has come close to the efficacy target of 80 per cent set by the WHO. Artemisinins have been the most successful antimalarial drugs since the 2000s, and the Gates Foundation is currently funding the development of the artemisinin RTS,S/AS01 vaccine, which is the only vaccine candidate currently in phase 3 clinical trials. The drug is designed for African infants and trials show it to be 55 per cent effective. Although the efficacy of RTS,S/AS01 is far from ideal, the drug could save hundreds of thousands of lives each year.[39]

Scientists at the University of Cape Town recently announced the development of a drug that kills all forms of malaria in a single dose. The drug, known as MMV390048, has had tremendous success on animals and will enter human trials next year. Though this new drug is an exciting development, many received the news of the drug cautiously since several promising antimalarial drugs have undergone years of human trials in the past decade, but none has achieved the success desired. MMV390048 is several years away from pharmacy shelves, if it ever gets there.[40]

A TOOL FOR EXPLORING THE IMPACT OF ERADICATION: INTERNATIONAL FUTURES

The International Futures (IFs) tool is unique because it models relationships across variables from a very wide range of key global systems for 183 countries from 2010 to 2100. Relationships are built in the model in two interconnected ways: first, by leveraging a very large set of historical data series (nearly 2 500 series in the most recent version of the model), and second, by evaluating extant academic literature. IFs has been used to shape expectations about global change and continuity and to formulate reasonable but aggressive policy choices to promote human development.

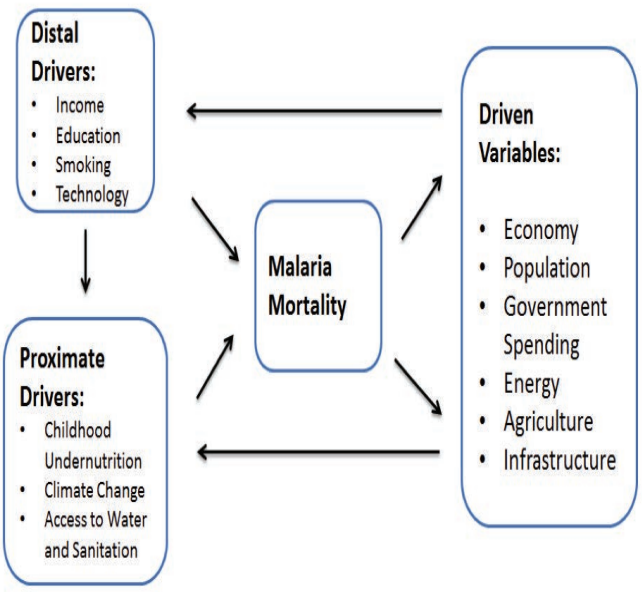
The system is built on a foundation of dynamically interacting sub-systems. These include population, economic, health, education, infrastructure, agriculture, energy, environment, governance, and international political modules.

The health module in IFs was greatly extended in support of Improving Global Health, the third volume in the Pardee Center's 'Patterns of Potential Human Progress flagship' series.[41] The module forecasts age, sex, and country-specific health outcomes for 15 categories of disease. These health outcomes have both backward and forward links to variables in other key systems of the model, including demography, the economy, and government spending. The disease categories, equations, and historical data used are described in detail in that volume. While acknowledging the more recent estimates[42] provided in Murray et al (2012) and the 2011 World Malaria Report, IFs software still relies on the WHO's *Global Burden of Disease* 2004 update[43] as its primary source of historical data (and will continue to do so until greater consensus is reached on the true scope of deaths related to malaria).

Both distal and proximate drivers shape changes in health outcomes. Distal drivers change slowly across generations and are responsible for long-term shifts in health outcomes. Building on the work of the Global Burden of Disease project,[44] income, years of completed education, technology, and smoking are the distal drivers of health in the IFs system. Proximate drivers of health outcomes are more disease-specific and can have shorter-term impacts on health outcomes. The direct proximate driver of malaria in IFs is childhood undernutrition, which is also affected by two other proximate drivers – global climate change and the lack of access to improved water and sanitation.[45]

A stylised representation of the treatment of malaria is shown in Figure 1. For a detailed explanation of the treatment of health and its forward impacts in the IFs model, please see the Patterns of Potential Progress volume *Improving Global Health*.[46]

Figure 1: Stylised representation of malaria linkages in IFs



Malaria No More:
Expectations for Eradication

between 2015 and 2050 Africa would experience...

DEATHS

- 12
million deaths

HEALTHY LIFE

+ 50
million years

LIVELIHOOD

$ + 2.50
million people living above $1.25/day in 2050

ECONOMY

+ 430
billion US$

PER CAPITA INCOME

> 30
US$ pp in 2050

Eradicating malaria would not solve all of Africa's social and economic problems; but it would be a step toward a healthier and more prosperous future.

REPRESENTING MALARIA ERADICATION

To explore and shape expectations around the unfolding of malaria eradication in Africa, this policy brief compares two scenarios in the IFs system. The first scenario is the Base Case of IFs, which represents a continuation of policy choices made since the end of the Cold War, as well as our best understanding of the unfolding of energy, agriculture, and environmental systems. The second scenario is called Malaria Eradication and models a decline in deaths related to malaria beginning in 2015, reaching full eradication in 2025, and remaining malaria free through 2050 (the horizon used for this analysis).

The Base Case calculates that, in 2015, over 800 000 people will die of malaria in Africa.[47] In this scenario – where policy choices and international aid continue as at present – deaths reduce at an annual rate of 3 to 4 per cent. By 2050, with continued improvements in income, technology, and education, we forecast that a business-as-usual scenario would lead to just under 150 000 deaths per year in Africa.

However, if African deaths from malaria were reduced to zero by 2025 and kept at that level through 2050, as in the Malaria Eradication scenario, 12 million deaths would be avoided. The two countries with by far the largest number of lives saved would be Nigeria and the DRC, with about 2,5 million deaths averted in each. The third highest number of deaths avoided would be in Tanzania, with over 600 000 deaths averted.

While 12 million deaths would be prevented in Africa, the population in 2050 would only be about six million larger than in the Base Case Forecast. This seemingly low population growth is mostly due to decreases in infant mortality, which, as discussed earlier, lead to reductions in the fertility rate. This would lead to a reduction in the birth rate of about three births per 10 000 people in the decade after the intervention, eventually converging to about one fewer birth per 10 000 people by the end of the time horizon. In addition, about 200 000 more chronic disease deaths occur in the Malaria Eradication scenario relative to the Base Case cumulatively across the time horizon because fewer people die from malaria.

By 2050, the population of Africa would be only about 0,03 per cent larger in a scenario in which malaria was fully eradicated by 2025. This difference in population would have small impacts on the overall size of the labour force, education spending, and health spending. However, the full elimination of malaria would lead to increases in overall economic output.

Comparing GDP at purchasing power parity across the time horizon shows that the Malaria Eradication scenario would increase overall output by over US$ 430 billion.[48] This economic growth outstrips the anticipated increase in population, and leads to an absolute rise in income per capita of over US$ 30 per person compared to the Base Case in 2050.

The increased economic output would stem mostly from improvements in productivity. Eradicating malaria in our scenario reduces the disability rate – the percentage of the population and labour force that suffer malaria-related morbidity rather than mortality. Total years of life living with a disability in Africa are reduced by more than 50 million years cumulatively when comparing the two scenarios.[49]

CONCLUSION

Malaria eradication would contribute nearly US$ 430 billion to Africa's economy by 2050, but it would also be an expensive investment. The smallpox eradication campaign of the 1960s and 1970s cost about US$ 1 billion (in current dollars) in total,[50] but malaria eradication would likely cost much more. It is already costing up to US$ 1 billion just to develop a vaccine against malaria[51] and far more for the ongoing efforts to control malaria and its impact. In fact, the WHO currently estimates that it will cost US$ 5,1 billion each year from now until 2020 just to reach malaria control targets.[52] Yet even a malaria eradication campaign that cost several billion dollars per year would be inexpensive relative to the economic benefits of malaria's elimination.

Economic costs and benefits aside, policymakers must consider the implications for African people. Eliminating the disease would prevent 12 million deaths and 50 million years of life lived with a disability by 2050. These humanitarian impacts should be reason enough to make malaria eradication a top priority. There are, of course, no silver bullets in promoting human development generally. Eradicating malaria would not solve all of Africa's social and economic problems; it would, however, be a step in the right direction and could contribute much to broader and more comprehensive efforts to truly transform the future of the continent.

NOTES

[1] A study by Murray et al gathered, reclassified and re-estimated data on the global mortality pattern for malaria from 1980 to 2010. These authors found that deaths in Africa grew from 493 000 in 1980 to a peak of 1 613 000 in 2004. This trend then turned and deaths declined to 2010 levels, reaching 1 133 000. The authors credit the international donor community for the drop in deaths between 2004 and 2010. Two important conclusions can be drawn from this study: first, their estimate of deaths from malaria is higher (by almost 18 per cent) than ours, which is taken from the WHO Global Burden of Disease (see World Health Organization, The Global Burden of Disease: 2004 Update, 2008). Their estimates are higher in relation to deaths of people aged five years and older. Our data estimates that over 13 per cent of malaria deaths occur in people five years or older. Second, the Murray et al study estimates that over 38 per cent of total deaths in Africa occur in that age group. See Christopher J L Murray, Alan D Lopez, Lisa C Rosenfeld et al, Global malaria mortality between 1980 and 2010: a systematic analysis, The Lancet 379 (9814) (2012), 413 -31. For yet another estimate of malaria deaths, see MDG 6: HIV/AIDS, malaria and other diseases: malaria indicators, Global Health Observatory Data Repository, World Health Organization, http://apps.who.int/gho/data/?vid=440 (accessed October 2012).

[2] Barry B Hughes, Randall Kuhn, Cecilia M Peterson et al, Improving global health: patterns of potential human progress, vol. 3, Boulder, CO, USA: Paradigm Publishers and New Delhi, India: Oxford University Press, 2011; IFs: The International Futures (IFs) modelling system, version 6.61 was used for the development of this report. The IFs software was initially developed by Barry Hughes and is based at the Frederick S. Pardee Center for International Futures, Josef Korbel School of International Studies, University of Denver, http://www.ifs.du.edu.

[3] UN Millennium Project, Coming to grips with malaria in the new millennium, Task Force on HIV/AIDS, Malaria, TB, and Access to Essential Medicines, Working Group on Malaria, Earthscan, London, 2005, 28.

[4] John L Gallup and Jeffrey D Sachs, The economic burden of malaria, Center for International Development at Harvard, Cambridge, 1998, 3, http://www.cid.harvard.edu/archive/malaria/docs/mal_wb.pdf (accessed January 2012). This type of malaria has a fatality rate of 15 to 20 per cent.

[5] Kimberly E Mace, Matthew F Lynch, John R MacArthur, et al, and Centers for Disease Control and Prevention (CDC), Grand rounds: the opportunity for and challenges to malaria eradication, MMWR, Morbidity and Mortality Weekly Report 60(15) (2011), 476-480, 476.

[6] UN Millennium Project, Coming to grips with malaria in the new millennium, 15.

[7] F Desmond McCarthy, Holger Wolf and Yi Wu, Malaria and growth, Policy Research Working Paper 2303, The World Bank, Development Research Group, Public Economics, 2000, 4,5, http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2000/04/19/000094946_00040605325255/additional/115515323_20041118104421.pdf (accessed September 2012).

[8] Though admittedly Haiti's malaria death rates are lower than those of most African countries. See Gallup and Sachs, The economic burden of malaria, 1. This statistic is reproduced in our 2010 estimates of malaria deaths in the Americas. Haiti has the highest rate and absolute deaths from malaria.

[9] Gallup and Sachs, The economic burden of malaria, 3.

[10] McCarthy, Wolf and Wu, Malaria and growth, 2, 12.

[11] Jeffrey S Hammer, The economics of malaria control, The World Bank Research Observer 8(1) (1993), 1-22, 9.

[12] Gallup and Sachs, The economic burden of malaria, 7.

[13] Jeffrey D Sachs, Macroeconomics and health: investing in health for economic development, Report of the Commission on Macroeconomics and Health, Geneva: World Health Organization, 2001, 32, http://whqlibdoc.who.int/publications/2001/924154pdf (accessed September 2012).

[14] UN Millennium Project, Coming to grips with malaria in the new millennium, 20.

[15] Barofsky, Jeremy, Claire Chase, Tobenna Anekwe et al, The economic effects of malaria eradication: Evidence from an intervention in Uganda, PDGA Working Paper No. 70, Program on the Global Demography of Aging, 2011, 3, http://www.hsph.harvard.edu/pgda/WorkingPapers/2011/PGDA_WP_70.pdf (accessed September 2012).

[16] Ibid., 15, 20.

[17] Donald J Pletsch and CT Ch'en, Economic and social effects of malaria control with some specific instances from Taiwan, Geneva: World Health Organization, 1954, 5 http://apps.who.int/iris/handle/10665/64287?mode=full (accessed September 2012).

[18] Robin Barlow, The economic effects of malaria eradication, The American Economic Review 57(2) (1967), 130-48, 143.

[19] Oliver Sabot, Allison Tatarsky, Shahina Aboobakar et al, Costs and financial feasibility of malaria elimination, Lancet 376(9752) (2010), 1604–15, 1604.

[20] Randall M Packard, Roll back malaria, roll in development? Reassessing the economic burden of malaria, Population and Development Review 35(1) (2009), 53-87, 76, 78.

[21] Nancy Birdsall, Economic analyses of rapid population growth, The World Bank Research Observer 4(1) (1989), 23-50, 26.

[22] Ibid., 30.

[23] Tadashi Yamada, Causal relationships between infant mortality and fertility in developed and less developed countries, Southern Economic Journal 52(2) (1985), 364-70, 368.

[24] Mark R Rosenzweig and T Paul Schultz, Consumer demand and household production: the relationship between fertility and child mortality, The American Economic Review 73(2) (1983), 38-42, 38.

[25] Yamada, Causal relationships between infant mortality and fertility in developed and less developed countries, 365.

[26] Eui Hang Shin, Socioeconomic development, infant mortality, and fertility: a cross-sectional and longitudinal analysis of 63 selected countries, Journal of Development Studies 13(4) (1977), 398-412, 400.

[27] Ibid., 400, 401.

[28] Deirdre A Joy, Edward Suh, Peter Beerli et al, Early origin and recent expansion of Plasmodium Falciparum, Science 300 (5617) (2003), 318-21, 318.

[29] Jane Achan, Ambrose O Talisuna, Annette Erhart et al, Quinine, an old anti-malarial drug in a modern world: role in the treatment of malaria, Malaria Journal 10(1) (2011), 144-156, 145.

[30] UN Millennium Project, Coming to grips with malaria in the new millennium, 18.

[31] Marcel Tanner and Don de Savigny, Malaria eradication back on the table, World Health Organization, http://www.who.int/bulletin/volumes/86/2/07-050633/en/ (accessed October 2012).

[32] Melinda French Gates, Prepared remarks by Melinda French Gates, Co-chair (speech, Seattle, WA, 17 October 2007), Bill and Melina Gates Foundation, http://www.gatesfoundation.org/speeches-commentary/Pages/melinda-french-gates-2007-malariaforum.aspx (accessed September 2012); Murray et al, Global malaria mortality between 1980 and 2010, 413.

[33] Brian Greenwood, Amit Bhasin and Geoffrey Targett, The Gates Malaria Partnership: a consortium approach to malaria research and capacity development, Tropical Medicine & International Health 17(5) (2012), 558-63, 558, 559.

[34] Greenwood, The Gates Malaria Partnership, 558, 559.

[35] Sachs, Macroeconomics and health, 28-29.

[36] World Health Organization, World malaria report 2010, 28.

[37] Ibid., 24.

[38] Ibid., 23.

[39] World Health Organization, World malaria report 2011, Geneva: World Health Organization, 2011, 36, http://www.who.int/malaria/world_malaria_report_2011/en/ (accessed September 2012); Salim Abdulla, Ajuza Jumanne, Nahya Salim, et al, Safety and immunogenicity of RTS,S/AS02D malaria vaccine in infants, The New England Journal of Medicine 359(24) (2008), 2533-44, 2533.

[40] Department of Science and Technology, South Africa, African research

identifies strong candidate for possible single-dose malaria cure, , 28 August 2012, http://www.mmv.org/newsroom/news/african-antimalarial-research-bears-first-fruit (accessed September 2012).

[41] Hughes et al, Improving global health.

[42] See Endnote 1 for a detailed explanation of the different estimates.

[43] World Health Organization, The global burden of disease: 2004 update, Geneva: World Health Organization, 2008.

[44] Colin Mathers was generous in providing equations of the project and advice in our work. See Colin D Mathers and Dejan Loncar, Projections of global mortality and burden of disease from 2002 to 2030, PLoS Med 3(11) (2006), 2011-2030, doi: 10.1371/journal.pmed.0030442 (accessed September 2012).

[45] In IFs global climate change affects childhood undernutrition through its impact on crop yields. The more direct effects of climate change on the lifecycles of the malaria parasites and mosquito vectors, which have been examined in numerous studies, are not currently included in IFs.

[46] Hughes et al, Improving global health.

[47] As noted earlier, the recent publication of Murray et al increased the estimate of malaria deaths globally, including in Africa. Much of the increase in deaths in Africa comes from adult deaths. The IFs model will continue to use the WHO Global Burden of Disease data as a source until greater consensus is reached on the true scope of deaths related to malaria. If a larger proportion of deaths from malaria came from adults than we estimate, the impact of reducing malaria would be greater. The conclusion of this policy brief addresses this.

[48] Taken as the cumulative difference between the Base Case and the Eradicate Malaria scenario discounted at 3 per cent annually.

[49] It should be noted that the impacts from the eradication of malaria calculated in this brief may be underestimated, especially the forward link to productivity. This is especially true if the estimates in Murray et al are more accurate than the WHO Global Burden of Disease. The former study estimates a larger number of adults die from malaria than the WHO estimates.

[50] This is based on the estimate made by Frank Fenner, Donald A Henderson, Isao Arita, Zdeněk Ježek and Ivan D Ladnyi, Smallpox and its eradication, Geneva: World Health Organization, 1988, 1364, that the smallpox eradication campaign cost approximately US$ 23 million each year between 1967 and 1979. Converting this to current dollars, we calculate a total cost of US$ 1 billion. Center for Global Development, Case 1: Eradicating smallpox, Center for Global Development, 6, http://www.cgdev.org/doc/millions/MS_case_1.pdf (accessed October 2012).

[51] Roll Back Malaria, Global Malaria Action Plan, Part II: The Global Strategy, 110, http://www.rbm.who.int/gmap/part2.pdf (accessed October 2012).

[52] Ibid., 101.

AFRICAN FUTURES PROJECT

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