The (Potential) Role of Economic Policy in Combating Neglected Tropical Diseases: A Case Study of Schistosomiasis in Uganda

Edward M. Whitney

Current Version: March 21, 2024

Introduction

Despite decades of efforts by policymakers, NGOs, and others, Neglected Tropical Diseases (NTDs) persist around the world (Ogongo et al., 2022; World Health Organization, 2015). The 2nd most common NTD in the world after Malaria, Schistosomiasis (shortened to Schisto below), is widely considered to be an infectious disease of poverty (World Health Organization, 2015; Centers for Disease Control, 2018). In many countries, a poor household is more likely to lack proper sanitation and access to adequate health care (Stevens 2014), both of which have been shown to be correlated with Schisto prevalence (Grimes et al. 2014). In addition, Schisto and similar diseases can negatively impact both the accumulation process and the stock of an individual's health capital, making it even more difficult for vulnerable and poor households to avoid being trapped in a state of poverty (Bonds et al., 2010).

The worldwide persistence of Schisto may partly be a consequence of the complicated relationship between Schisto and the human-natural environment, which spans three distinct yet interconnected domains. Within the public health domain, common approaches to combating the disease include school-based and community-based distributions of drugs like Praziquantel for treatment of existing infections (King et al., 2020). Although additional efforts focus on changing behavioral decisions associated with water, sanitation and hygiene (WASH), poor households face constraints on their decisions related to WASH behaviors that cannot be lifted by information campaigns alone (Torres-Vitolas et al., 2023). Additionally, some of the primary behaviors associated with transmission of the disease, such as fishing, fall squarely within the economic domain and, consequently, are likely to respond to changes in policy shocks that target economic objectives. Furthermore, the well-documented relationship between fishing effort and future fish stocks implies that fisheries management policies, which often have a focus on both the economic and biological domains, can potentially also have an impact on prevalence of Schisto.

The overarching goal of this study is to better understand how policies specific to one of the three domains within the human-natural environment can have ancillary consequences—costs or benefits—for the other domains. In pursuit of this goal, I adopt a coupled modeling approach to represent the interconnectedness of the three domains. Specifically, I link a computable general equilibrium (CGE) model of a small economy to an epidemiological model that represents the dynamics of Schisto and a biological model that represents the growth process of the fish stock targeted by fishers in the economy. The motivation for linking the public health and economic domains is informed by the well-documented relationship between economic activity and disease burden (Gallup and Sachs, 2001; Cole and

Neumayer, 2006; Ismahene, 2022). The methodology that I use to connect these two domains is developed in a manner that is consistent with previous interdisciplinary efforts to study the relationship between Schisto and the human-natural environment (Bonds et al., 2010; Ngonghala et al., 2014; Garchitorena et al., 2017). I adopt methods from previous bioeconomic studies to link the economic domain and the biological domain, thereby allowing me to account for the critically important relationship between fishing effort and future fish stocks (Manning, Taylor, and Wilen, 2018; Gilliland, Sanchirico, and Taylor, 2019; Lindsay et al., 2020).

My dissertation contributes to the current literature in two important ways. First, by connecting a system of disease dynamics for Schistosomiasis to a CGE model of a small economy, I am able to account for differences in sectoral-level contributions to overall output, which is a novel approach that is not possible using aggregate measures of output as adopted in previous studies (e.g., Bonds et al., 2010; Ngonghala et al., 2014; Garchitorena et al., 2017). This heterogeneity can be of first-order importance when the amount of labor employed in a particular sector, such as fishing, correlates with disease transmission. Furthermore, the coupled human-natural model provides a powerful tool for understanding how policies that target one domain (e.g., the local economy) can result in ancillary consequences for another domain (e.g., the ecosystem).

Second, I explicitly account for exposure time to the disease in the system of disease dynamics. This addition is critical when labor time in one sector is correlated with exposure to the disease. It is generally accepted that behavioral decisions—along with socioeconomic status, gender, and ethnicity (Moira et al., 2007)—can be factors in transmission of diseases such as Schisto (Garchitorena et al., 2017). In many communities where Schisto is prevalent, specific economic sectors such as fishing represent both a significant source of income for the local economy and a significant source of exposure time to the parasite that causes the disease. In these settings, including a measure of exposure time is necessary to understand whether and how policy shocks could influence welfare outcomes via disease dynamics.

To demonstrate the importance of accounting for exposure time and sector-level contributions to aggregate output, I posit a scenario wherein a change in fisheries management policy results in a relaxation of restrictions on fishing effort. Such a policy change would lead to an increase in labor demand (and thus output) in the fishing sector. Ignoring possible price responses, this policy would result in an increase in aggregate output. If one were to simulate the impact of this policy change using a model built with an assumption that disease prevalence declines over time as aggregate income increases, the results might suggest that such a policy change would unambiguously lead to a decline in disease prevalence. However, the amount of fishing labor, and therefore exposure time to the disease, has actually increased. This increase in exposure time could dampen, or perhaps even reverse, the reduction in disease prevalence accruing from the increase in aggregate output.

My dissertation also contributes to the literature by analyzing the role of policies that target specific economic objectives can play in disease mitigation efforts. For the most part, efforts to reduce Schisto prevalence have largely focused on reducing prevalence in human hosts via the implementation of mass drug administrations (MDA) of inexpensive treatments such as Praziquantel. Integrated approaches to management of Schisto prevalence have combined MDA programs with other methods, including environmental interventions, such as molluscicides or reintroduction of natural predators of snails, improved WASH facilities, information-based interventions. Results from previous studies demonstrate the importance of a integrated approach to combating prevalence of the disease (Castonguay et al., 2020; Sun et al., 2017; Inobaya et al., 2014). However, the potential role that economic policy can play as a means to influence behavior in this context has received less attention.

In this study, I use a coupled epidemiological-biological-economic model of the human-natural environment to examine how three types of policies interact with prevalence of Schisto. Using originally collected microdata to parameterize the economic component, I model labor employed in each sector as a function of disease prevalence. In the epidemiological component, I model two parameters—the rate of human exposure to the disease and the mortality rate of the parasite in the human host—as functions of aggregate output in the local economy, and I also include an explicit measure of exposure time. To account for the relationship between fishing effort and the fish stock, I also include a dynamic model of the fish stock targeted by the local fishing industry. Using this novel coupled human-natural model, I simulate the impact of three different types of policy shocks: a policy designed to increase yields in cash-crop production by smallholder households, a fisheries management policy designed to reduce overfishing, and a community-wide distribution of treatment for Schisto. For each type of policy, I identify the primary effects of the policy shock and any ancillary consequences of the policy for other components of the model.

Bibliography

Bonds, Matthew H. et al. (2010). "Poverty trap formed by the ecology of infectious diseases". In: *Proceedings of the Royal Society B: Biological Sciences* 277.1685, pp. 1185–1192. DOI: 10.1098/rspb.2009.1778. eprint: \url{https://royalsocietypublishing.org/doi/pdf/10.1098/rspb.2009.1778}. URL: %5Curl%7Bhttps://royalsocietypublishing.org/doi/abs/10.1098/rspb.2009.1778%7D.

Castonguay, François M. et al. (2020). "Cost-effectiveness of combining drug and environmental treatments for environmentally transmitted diseases". In: *Proceedings of the Royal Society B: Biological Sciences* 287.1933, p. 20200966. DOI: 10.1098/rspb.2020.0966.

Centers for Disease Control (2018). *CDC - Schistosomiasis*. Accessed 2019-4-11. URL: https://www.cdc.gov/parasites/schistosomiasis/index.

Cole, Matthew A. and Eric Neumayer (Aug. 2006). "The impact of poor health on total factor productivity". In: *The Journal of Development Studies* 42.6, pp. 918–938. DOI: 10.1080/00220380600774681. URL: https://doi.org/10.1080/00220380600774681.

Gallup, J L and J D Sachs (Jan. 2001). "The economic burden of malaria". In: *Am J Trop Med Hyg* 64.1-2 Suppl, pp. 85–96.

Garchitorena, A. et al. (2017). "Disease ecology, health and the environment: a framework to account for ecological and socio-economic drivers in the control of neglected tropical diseases". In: *Philosophical Transactions of the Royal Society of London B: Biological Sciences* 372.1722. ISSN: 0962-8436. DOI: 10.1098/rstb.2016.0128. eprint: http://rstb.royalsocietypublishing.org/content/372/1722/20160128.full.pdf. URL: http://rstb.royalsocietypublishing.org/content/372/1722/20160128.

Gilliland, Ted E., James N. Sanchirico, and J Edward Taylor (2019). "An integrated bioeconomic local economy-wide assessment of the environmental impacts of poverty programs". In: *Proceedings of the National Academy of Sciences* 116.14, pp. 6737–6742. DOI: 10.1073/pnas.1816093116. eprint: https://www.pnas.org/content/116/14/6737.full.pdf. URL: https://www.pnas.org/content/116/14/6737.

Grimes, Jack E. T. et al. (Dec. 2014). "The Relationship between Water, Sanitation and Schistosomiasis: A Systematic Review and Meta-analysis". In: *PLOS Neglected Tropical Diseases* 8.12, pp. 1–12. DOI: 10.1371/journal.pntd.0003296. URL: https://doi.org/10.1371/journal.pntd.0003296.

Inobaya, M. T. et al. (2014). "Prevention and control of schistosomiasis: a current perspective". In: *Research and Reports in Tropical Medicine* 5.1722, pp. 65–75. DOI: doi.org/10.2147/RRTM.S44274.

Ismahene, Y. (2022). "Infectious Diseases, Trade, and Economic Growth: a Panel Analysis of Developed and Developing Countries". In: *J Knowl Econ.* 13.3, pp. 2547–83.

King, Charles H. et al. (July 2020). "Impact of Different Mass Drug Administration Strategies for Gaining and Sustaining Control of Schistosoma mansoni and Schistosoma haematobium Infection in Africa". In: *The American Journal of Tropical Medicine and Hygiene* 103.1_Suppl, pp. 14–23. DOI: 10.4269/ajtmh.19-0829. URL: https://doi.org/10.4269/ajtmh.19-0829.

Lindsay, Amanda R. et al. (2020). "Evaluating sustainable development policies in rural coastal economies". In: *Proceedings of the National Academy of Sciences* 117.52, pp. 33170–33176. ISSN: 0027-8424. DOI: 10.1073/pnas.2017835117. URL: https://www.pnas.org/content/117/52/33170.

Manning, Dale T., J. Edward Taylor, and James E. Wilen (Jan. 2018). "General Equilibrium Tragedy of the Commons". In: *Environmental and Resource Economics* 69.1, pp. 75–101. ISSN: 1573-1502. DOI: 10.1007/s10640-016-0066-7. URL: https://doi.org/10.1007/s10640-016-0066-7.

Moira, Angela Pinot De et al. (2007). "Microgeographical and tribal variations in water contact and Schistosoma mansoni exposure within a Ugandan fishing community". In: *Tropical Medicine & International Health* 12.6, pp. 724–735. DOI: 10.1111/j.1365-3156.2007.01842.x.

Ngonghala, Calistus N. et al. (Apr. 2014). "Poverty, Disease, and the Ecology of Complex Systems". In: *PLOS Biology* 12.4, pp. 1–9. DOI: 10.1371/journal.pbio.1001827. URL: https://doi.org/10.1371/journal.pbio.1001827.

Ogongo, Paul et al. (2022). "The Road to Elimination: Current State of Schistosomiasis Research and Progress Towards the End Game". In: *Frontiers in Immunology* 13. ISSN: 1664-3224. DOI: 10.3389/fimmu.2022.846108. URL: https://www.frontiersin.org/articles/10.3389/fimmu.2022.846108.

Stevens, Philip (2014). *Diseases of poverty and the 10/90 gap.* International Policy network.

Sun, Le-Ping et al. (Mar. 2017). "A multidisciplinary, integrated approach for the elimination of schistosomiasis: a longitudinal study in a historically hyper-endemic region in the lower reaches of the Yangtze River, China from 2005 to 2014". In: *Infectious Diseases of Poverty* 6.1, p. 56. ISSN: 2049-9957. DOI: 10.1186/s40249-017-0270-x. URL: https://doi.org/10.1186/s40249-017-0270-x.

Torres-Vitolas, Carlos A. et al. (May 2023). "Behaviour change interventions for the control and elimination of schistosomiasis: A systematic review of evidence from low- and middle-income countries". In: *PLOS Neglected Tropical Diseases* 17.5. Ed. by Alberto Novaes Ramos, e0011315. ISSN: 1935-2735. DOI: 10.1371/journal.pntd.0011315. URL: http://dx.doi.org/10.1371/journal.pntd.0011315.

World Health Organization (2015). "Schistosomiasis: number of people treated worldwide in 2013". In: *Weekly Epidemiol Rec.* 90.5, pp. 25–32. URL: https://www.who.int/wer/2015/wer9005.pdf.