Title: Considering the interaction between TB and the economy: time to integrate epidemiological and economic models

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Word count: 1077

Tables: 0

Figures: 1

References: 15

Running head: Linking epidemiological and economic models

Funding statement: This work was funded by Johnson and Johnson

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Key words: tuberculosis, epidemiology, modelling, economics

Dear Editor,

Poverty is both a cause and consequence of tuberculosis (TB)[1] . Reducing the economic impact of TB on affected households is a target of the World Health Organisation (WHO) TB strategy [2]. Poverty alleviation and action on other social determinants of TB are also likely to be important for reaching the Sustainable Development Goals (SDGs) and meeting WHO targets for reductions in TB disease burden[2]. TB may also have a wider macro-economic impact, through spending on healthcare and potential effects of morbidity and mortality on productivity. Understanding the interactions between economic growth, poverty and TB is critical to reducing the health and economic burden of TB and to determining optimal investment in TB services and technologies. Mathematical and economic modelling can play a key role in understanding these interactions and informing the case for national and global investment in TB services.

The economic evaluation of the benefits of new technologies typically take a micro-economic (health sector) perspective, focussing on the health sector costs and health gains of control measures. TB economic evaluations have been extended to include (partial) societal perspectives of TB investment, and to incorporate financial and indirect costs for affected individuals and their households in cost-effectiveness analyses[3]. Analyses have also considered the distribution of health gains and costs across populations (for example socio-economic quintiles), including the consequences in terms of increased health equity and reduction in catastrophic costs due to TB[4]. In terms of broader productivity and societal value, efforts such as the Copenhagen Consensus have applied Benefit Cost Analysis to TB to inform the selection of interventions across social and economic development objectives[5]. While these approaches can capture some broader aspects of productivity and welfare, they are not grounded in an empirical assessment of macro-economic impacts.

It is not clear whether such approaches accurately capture the wider economic benefits of increased investment in TB services. Extending health economic analyses beyond the partial equilibrium (health sector) perspective into the general equilibrium (macroeconomic) domain may provide further evidence to support investment in TB services that resonates with Ministries of Finance, and provide data to validate (or not) the use of simpler approaches.

To more fully explore the impact of TB on GDP growth in both the short and long term, it is necessary to capture the potential for spill-over effects across sectors, between consumption and investment, and feedback between health outcomes and the economy. For some health conditions these feedbacks may be negligible, but, for TB, economic feedback effects on health outcomes may be substantial. For example, there is evidence that increased spending on social protection and cash transfers are associated with reductions in TB incidence [6, 7]. Since the risk factors associated with TB are closely linked to economic welfare, a robust and dynamic macroeconomic analysis of TB and TB-related policies may allow us to capture not only the impacts of morbidity, mortality and healthcare expenditure on the economy, but also the feedback effects of economic changes on TB.

Computable General Equilibrium (CGE) models are one possible approach to this challenge. CGE models are multi-sector macroeconomic (or whole-economy) models and have been recognised and recommended by the WHO as a tool for health policy analysis for several years. Using CGE models in health applications allows us to simultaneously capture the impact of changes in healthcare expenditures, health-related investments, and changes in population health across all sectors of the economy.

To date CGE models have only been applied in a limited way to TB, often as part of more general analyses[8], and there have been no efforts to fully integrate CGE and TB models into one framework. CGE modelling has been applied to other infectious diseases including HIV/AIDS[9], pandemic flu[10, 11], and more recently Covid-19[12]. One previous study has explored the feedback between an infectious disease and the economy by integrating an epidemiological model of malaria transmission, demographic models and a society-wide macroeconomic framework to model the interaction between malaria and macroeconomics in Ghana[13].

Here we propose an integrated macro-economic framework for analysing the relationship between tuberculosis and the macro-economy (Figure 1) that could be used to support the investment case for TB services and interventions. The framework is based on the approach previously applied to Malaria[13]. The framework combines a dynamic epidemiological model of TB, a demographic model and a CGE (whole economy) model, allowing for assessment of both the impact of health policies on the economy and the impact of economic policies' on TB burden.

The TB model simulates the number of TB cases and deaths. These estimates feed into the CGE model through effects of TB excess mortality and morbidity on the demographics and the availability of labour and through public and private health expenditure. There are many pathways through which the CGE model can influence the TB model. Economic policies may alter the prevalence of risk factors for TB such as low BMI. It may also affect the affordability of health services. In Figure 1 we illustrate one potential pathway: increased household wealth allows increased expenditure on food and use of clean cooking fuels which lead to increases in BMI and reductions in exposure to indoor air pollution (IAP). These in turn lead to reduced risks of developing TB. Many other factors also affect the risk of developing TB and could be incorporated into the proposed framework, building on existing conceptual frameworks for quantifying the effects of social protection on TB[14] and evidence on the prevalence of risk factors in specific settings[15].

We understand such models are complex and cannot be developed for all countries. However, we believe that this approach has the potential to generate new evidence to validate and improve the pragmatic methods that are currently employed for planning and advocacy purposes. As we live through COVID-19, the relationships between the economy, poverty and health are increasingly being observed yet they have existed for TB for centuries. Our future work will explore the application of this framework in India, but we also hope that others will begin to explore how best to link different types of economic and epidemiological models to inform TB policy and fund and support balanced collaboration between macro-economists, micro-economists and epidemiological modellers. There remain many outstanding challenges in how to conceptualise and parameterise the different feedback loops between economic and epidemiological models, and substantial data needs; we call for an active community of researchers to continue to develop and explore a broader range of economic approaches to support investment in TB services.

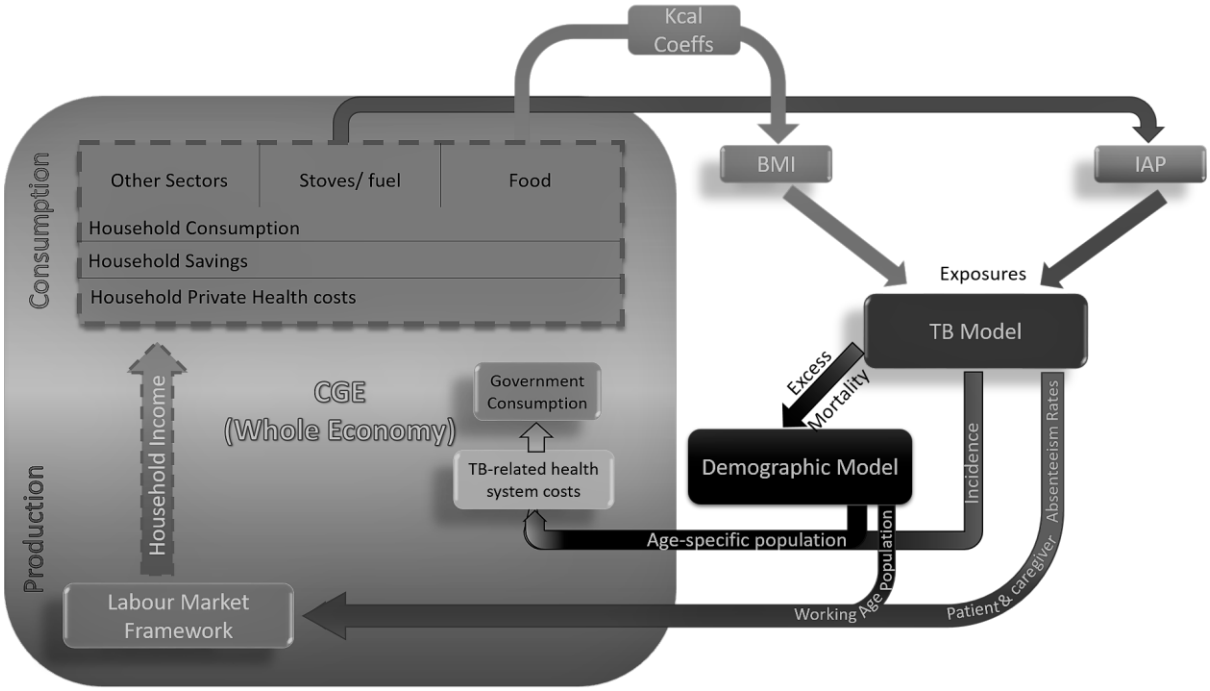

Figure 1. Graphical representation of the integrated modelling framework. The proposed framework consists of 3 components: a TB model that generates estimates of TB cases and deaths; a demographic model which simulates population growth and age structure; a CGE (whole economy model) which simulates government and household consumption and production across sectors. The TB model influences the demographic model via TB mortality. The demographic and TB model influence the CGE model via the labour force and government expenditure on health care. Feedback from the CGE model to the TB model is illustrated by changes to risk factors for TB (body mass index (BMI) and exposure to indoor air pollution (IAP)) as a result of economic policies.

References

1. Hargreaves JR, Boccia D, Evans CA, Adato M, Petticrew M, Porter JD. The social determinants of tuberculosis: from evidence to action. Am J Public Health. 2011;101(4):654-62.
2. Uplekar M, Weil D, Lonnroth K, Jaramillo E, Lienhardt C, Dias HM, et al. WHO's new end TB strategy. Lancet. 2015;385(9979):1799-801.
3. Laurence YV, Griffiths UK, Vassall A. Costs to Health Services and the Patient of Treating Tuberculosis: A Systematic Literature Review. Pharmacoeconomics. 2015;33(9):939-55.
4. Verguet S, Riumallo-Herl C, Gomez GB, Menzies NA, Houben R, Sumner T, et al. Catastrophic costs potentially averted by tuberculosis control in India and South Africa: a modelling study. Lancet Glob Health. 2017;5(11):e1123-e32.
5. Vassall A. Health Tuberculosis Perspective paper. Benefits and cosst of the tuberculosis targets for the post-2015 development agenda. Copenhagen: Copenhagen Consensus Centre; 2014.
6. Carter DJ, Glaziou P, Lonnroth K, Siroka A, Floyd K, Weil D, et al. The impact of social protection and poverty elimination on global tuberculosis incidence: a statistical modelling analysis of Sustainable Development Goal 1. Lancet Glob Health. 2018;6(5):e514-e22.
7. Siroka A, Ponce NA, Lonnroth K. Association between spending on social protection and tuberculosis burden: a global analysis. Lancet Infect Dis. 2016;16(4):473-9.
8. Ahmed SA, Baris E, Go DS, Lofgren J, Osorio-Rodarte I, Thierfelder K. Assessing the Global economic and poverty effects of antimicrobial resistance. Washington: World Bank; 2017.
9. Kambou G, Devarajan S, Over M. The economic impact of AIDS in an African Country: simulations with a computable general equilibrium model of Cameroon. Journal of African Economics. 1992;1(1):109-30.
10. Beutels P, Edmunds WJ, Smith RD. Partially wrong? Partial equilibrium and the economic analysis of public health emergencies of international concern. Health Econ. 2008;17(11):1317-22.
11. Keogh-Brown MR, Smith RD, Edmunds JW, Beutels P. The macroeconomic impact of pandemic influenza: estimates from models of the United Kingdom, France, Belgium and The Netherlands. Eur J Health Econ. 2010;11(6):543-54.
12. Keogh-Brown MR, Jensen HT, Edmunds JW, Smith RD. The impact of Covid-19, associated behavious and policies on the UK economcy: a computable general equilibrium model. Social Science and Medicine. 2020;In press.
13. Smith RD, Keogh-Brown MR, Chico RM, Bretscher MT, Drakeley C, Jensen HT. Will more of the same achieve malaria elimination? Results from an integrated macroeconomic-epidemiological-demographic model. American Journal of Tropical Medicine and Hygiene. 2020;In Press.
14. Boccia D, Rudgard W, Shrestha S, Lonnroth K, Eckhoff P, Golub J, et al. Modelling the impact of social protection on tuberculosis: the S-PROTECT project. BMC Public Health. 2018;18(1):786.
15. Oxlade O, Murray M. Tuberculosis and poverty: why are the poor at greater risk in India? PLoS One. 2012;7(11):e47533.