Novel economic perspectives on prevention and treatment: case studies for paediatric, adolescent and adult infectious and chronic diseases
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Document Version
Publisher's PDF, also known as Version of record

Publication date:
2015

Link to publication in University of Groningen/UMCG research database

Citation for published version (APA):

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Summary
Changes in population health status are known to influence government fiscal transfers both in terms of lost tax revenue and increased expenditure for health and social services. To estimate the fiscal impact of changes in morbidity and mortality attributed to rotavirus immunisation, we developed a government perspective model to estimate discounted net tax revenue for Ghana and Vietnam. The model derived the impact of rotavirus morbidity and mortality on lifetime productive capacity and related tax transfers, and demand for government transfers in relation to education and healthcare in immunized and non-immunized cohorts. The discounted age-specific net tax revenue was derived by deducting transfers from gross taxes and discounting for time preference. In Ghana, taking into account immunisation costs, tax and transfers, the estimated net discounted tax for the immunized cohort was estimated to generate $2.6 billion in net taxes up to age 65. In Vietnam, the net revenue attributed to the immunised cohort reached $55.17 billion suggesting an incremental benefit of approximately $29 million. We posit that the government perspective fiscal framework described here is a valid approach for estimating how governments benefit from investments in immunisation that can be considered supplementary to conventional cost-effectiveness approaches for defining value.

Introduction
In 2009 the WHO released the WHO Guide to Identify the Economic Consequences of Disease and Injury. Within the WHO guide the impact of population health on government spending and expenditures was described. Specifically, the report acknowledged that poor health can impact governments’ fiscal accounts both in terms of lost tax revenue and increased transfers costs. Despite acknowledging that population health influences
fiscal consequences for governments, the report provided few examples of the ways in which population health impacts government revenues and transfers. In the context of low and middle income countries this is an important relationship to consider because the ability of governments to raise revenue through taxation is an integral part of development⁴.

The conventional approach for evaluating health care expenditure is often performed at the program level, using cost-effectiveness analysis to achieve technical efficiency. Such an analysis is normally performed by focusing on health service costs and often ignoring the downstream indirect costs of changes in health status that improve our understanding of the broader economics of healthcare. This is particularly salient for immunisation where the benefits accrue over many generations. Consequently, applying a longer time perspective could provide a more complete picture of the value of vaccines³.

In fiscal terms, transfers between citizens and state in relation to health status changes have been mostly ignored in cost-effectiveness analysis on the belief there is no welfare gain or loss associated with transfers and taxes according to welfare economics⁵. While this may be true from the welfare economic perspective, from a government perspective this approach is flawed because lost taxes and transfers represent real cost for government. For example, an analysis conducted in the UK on the costs of ill-health in working aged adults reported that approximately 90% of the costs were attributed to increased transfer payments for time off work and lost tax revenue⁶.

The relationship between health and economic growth is one of the cornerstones of development economics¹,⁷. More specifically, health status is a determinant of productivity which can be shown to influence economic growth⁷. In fiscal terms, if one considers the relationships between health, productivity and economic growth, and the established relationship between economic growth and government tax revenue⁸, a rationale can be put forward for exploring the ‘government perspective’ associated with investments in health. The underlying premise of such analyses is that changes in health status in current and future working populations will have fiscal implications for government. Therefore, population health status changes linked to specific program investments can be shown to influence government tax revenue – in much the same way that investments in education have been shown to translate into future government taxes⁹. The burden of rotavirus in low and middle income countries (LMIs) is often immense. In 2008 the WHO estimated 453,000 deaths attributed to rotavirus with the majority of these occurring in LMI countries¹⁰. Additionally, rotavirus poses significant direct
costs for families and healthcare services resulting in clinic visits, diagnostics, medicines and hospitalisations\textsuperscript{11, 12}. Furthermore, it has also been shown that the costs attributed to lost productivity are often higher than the direct medical costs of rotavirus\textsuperscript{13}.

To understand the relationship between investments in rotavirus immunisation and resulting changes in morbidity and mortality with corresponding consequences for government accounts, we apply a government perspective framework to adult immunisation costs to determine the return on investment in future discounted net tax revenue. The aim is to estimate to what extent the fiscal benefits associated with vaccinating children against rotavirus will exceed the costs of immunisation. It is thought that understanding the relationship between health and future tax revenue linked to mortality changes can contribute to demonstrate the fiscal sustainability linked to public investments in immunisation programs.

\textbf{Materials and Methods}

A government perspective fiscal accounting model was developed to evaluate changes in rotavirus attributed morbidity and mortality in Ghana and Vietnam, based on a previously described framework\textsuperscript{14}. The model employed a modified generational accounting framework typically used by Treasury and other international organisations for modelling the intertemporal consequences of fiscal policy and changes in population dynamics\textsuperscript{15}. The metrics evaluated were the discounted net tax revenue (NPV) and discounted gross tax receipts attributed to changes in population health status and labour force participation. Labour force participation was defined mainly in terms of survival and labour supplied. Moreover, the corresponding labour loss for families that will care for the not-immunized sick subjects was also considered.

The survival of an average cohort was simulated based on the current life-tables in each country. For simplicity we did not change any long-term demographic changes. Rotavirus immunisation efficacy for Ghana and Vietnam was obtained from previous economic studies performed in each country\textsuperscript{16, 17}. Both Ghana and Vietnam were deemed as appropriate for such an analysis due to their growing economies, the existence of an organised tax and social insurance system as well as the epidemiology of rotavirus infections. Vaccine coverage rates and costs of treating rotavirus cases were obtained from previous cost-effectiveness models\textsuperscript{16, 17}. The average cost of rotavirus immunisation was estimated from publicly available prices applied to the immunisation schedule for the two vaccines\textsuperscript{18}.
To reflect the government perspective we quantified direct transfers from Ghana and Vietnam governments to immunised and non-immunised cohorts. Consistent with the generational accounting framework, transfer costs were inflated at the expected rates of 4% and 5.1%, for Ghana and Vietnam, respectively\textsuperscript{19, 20}. The model accounted for rotavirus specific health costs and age-specific per capita expenditure over the lifetime of the model. The rotavirus specific health costs accounted for different severity health states reported in cost-effectiveness studies for each country\textsuperscript{16, 17}. For both models the age-specific per-capita health cost was derived from average expenditure reported by the Ministry of Health. Enrolment rates for each education level were derived from national statistics and subsequently, age-specific education costs were estimated for both countries\textsuperscript{21, 22, 23}.

Transfers from citizens to state in the form of taxes and social contributions were integral to the model for assessing the fiscal impact of health investments. Consequently, future labour force contributions of immunised and non-immunised cohorts were employed. Data on average wages, age-specific unemployment and economic activity originated from the household surveys for each country\textsuperscript{21, 23}. Because the average wage is derived from a cross section of the community it is not necessary to adjust for variations in socioeconomic status.

In both models economic activity was adjusted for age-specific unemployment and labour force participation applied to immunized and unimmunized cohorts. In addition, an age-specific earnings pattern was calibrated for each country to reflect the effect of experience in per-capita earnings. In the model taxes were derived from the age-specific earnings using a disaggregated approach to account for direct and indirect taxes and social contributions that are collected in a similar fashion to taxes. In Ghana both the value added tax (VAT) levied at 10.5% and the National Health Insurance Levy of 2.5% were applied to disposable income\textsuperscript{24}. In Vietnam the 10% value added tax was applied to disposable income expenditure. An average income tax burden of 7.5% based on the two lowest tax bands was applied to wages which corresponded with the average salary for Vietnam\textsuperscript{25}. Additionally, mandatory unemployment insurance of 1%, and health insurance of 1.5% was applied to wages. To account for unreported economic activity an adjustment was applied to tax revenues based on reported estimates of the shadow economy for each country\textsuperscript{26}. Specifically, the scale of shadow economy was set at 45% and 16% for Ghana and Vietnam, respectively.

Net taxes represent the difference between lifetime taxes paid after deducting lifetime direct transfers received. In the model all taxes and transfers are age-specific to represent the fiscal life course and the point of time at which
fiscal transactions occur. In summary, in early ages of life the immunized and unimmunized cohorts are net recipients of government transfers in the form of healthcare and education. As the cohorts age and reach working age the cumulative gross taxes increase and government transfers are minimal. The model horizon was set at 65 years from birth. This age cut-off point was used since there was limited data on average earnings, pensions and consumption in later ages. The costs of rotavirus immunisation are treated as an investment that appears in the transfer costs for these cohorts. Therefore, to reflect the present value of investing in rotavirus vaccination, we estimate the net present value (NPV) and the downstream lifetime taxes and transfers of the immunized cohort as follows:

\[
\text{NPV} = \sum T (R_t - E_t) / (1 + r)^t - K_0(t)
\]

- \(R_t\) = Sum of gross taxes paid
- \(E_t\) = Sum of age-specific direct government expenditure per cohort over lifetime (e.g., education, health care)
- \(r\) = Rate of discount
- \(T\) = Current life expectancy
- \(K_0\) = Vaccine purchasing costs

Consistent with the cost-effectiveness studies for these countries costs in the model are discounted back to the original age of rotavirus vaccination to establish the net present value (NPV) of the investment decision using a discount rate of 3%. Previous cost-effectiveness models for Ghana and Vietnam were reproduced in order to simulate the epidemiology, mortality, morbidity indirect and direct medical costs during the first five years of life\[^{16,17}\].

Consistent with the cost-effectiveness studies for these countries costs in the model are discounted back to the original age of rotavirus vaccination to establish the net present value (NPV) of the investment decision using a discount rate of 3%. Previous cost-effectiveness models for Ghana and Vietnam were reproduced in order to simulate the epidemiology, mortality, morbidity indirect and direct medical costs during the first five years of life\[^{16,17}\].

**Results**

To illustrate the fiscal flows over time the net tax revenue for immunised cohorts up to the age of 65 is depicted in Figure 1 and Figure 2 for Ghana and Vietnam, respectively. The left Y-axis illustrates the net discounted tax revenue for the immunised cohort. In addition, to illustrate the differences between the immunised and non-immunised cohorts the differential or incremental net discounted tax between the two cohorts is illustrated (right Y-axis). For both countries net discounted tax curves share similar features
with negative net taxes in the early age of life until entering employment. In Ghana, the breakeven age was 33 for the immunised cohorts (Figure 1). The breakeven age is the age at which all transfers, including vaccination costs for the immunised cohort are counterbalanced by government revenues. The upward trajectory to age 50 and beyond reflects increased cumulative taxes paid and very limited transfers received during working ages. The curves for the immunised cohort in Vietnam and the incremental net discounted tax between the immunised and the non-immunised cohorts (Figure 2) share similar features to that of Ghana with negative net taxes early in life and positive net taxes after breaking even at age 43.

The cost of immunising a single birth cohort (n = 528,887) in Ghana was estimated at $4.66 million. At age 65 the immunised cohort is expected to have
generated a total discounted gross tax of $3.35 billion. The cohort is expected to generate, at year 65, a total present value of costs for the government equal to $761.21 million in terms of transfer for health costs and education. By taking into account vaccination costs, tax and transfers, the estimated net discounted tax for the immunized cohort at years 65 was estimated at $2.591 billion suggesting positive return for the government in the long-run. The corresponding net discounted tax for the non-immunised cohort was also positive at $2.582 billion which was reduced by $8.7 million compared to the immunized cohort.

In Vietnam, the total vaccination cost for a single cohort (n = 1,485,000) was estimated at $13.81 million. At year 65, the estimated present value of discounted tax for the immunised cohort was estimated at $65.99 billion, with
transfer costs totalling $9.82 billion up to the age of 65. The discounted net tax was estimated at $55,166 billion. The corresponding net discounted tax, at years 65 for the non-immunised cohort, was estimated at $55,138 billion suggesting an incremental benefit of approximately $28.8 million. The fiscal break-even point was at year 35 when tax revenue start to counterbalance transfers for education and health for both the immunized and unimmunized cohorts.

**Sensitivity analysis**

Deterministic one-way sensitivity analysis was conducted to assess the sensitivity of the model to key parameters. Key input variables were arbitrarily varied by (±30%) and its influence on net discounted tax of the immunised cohort at age 65. Figures 3.1 and 3.2 illustrate the key variables which the result was sensitive to for Ghana and Vietnam, respectively. As expected, discounted net tax was more sensitive to the selection of the discount rate and the productivity growth i.e. the annual increase of earnings per capita. Since the framework used here is largely dependent on discounted lifetime flows, employing a higher discount rate may influence the results. The sensitivity analysis showed that the immunised cohort consistently generated a positive lifetime net discounted tax. The magnitude of shadow or informal economy appeared to be less influential. Price was not a parameter which the results were sensitive to. This is because the cost of immunising the population is small compared to the benefits that this framework generates.

Figure 3.1 Sensitivity analysis [±30%]: Differential discounted net tax revenue for immunised cohort (n = 528,887) in Ghana in year 65, in millions USD

<table>
<thead>
<tr>
<th>Variable</th>
<th>Net discounted tax, (year 65; million USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wage productivity growth</td>
<td>$55,000</td>
</tr>
<tr>
<td>Discount rate</td>
<td>$55,000</td>
</tr>
<tr>
<td>Magnitude of shadow economy</td>
<td>$55,000</td>
</tr>
<tr>
<td>Vaccine price per dose</td>
<td>$55,000</td>
</tr>
</tbody>
</table>
Discussion

Estimating the fiscal consequences of health status changes is reliant on estimating productivity changes and how these changes translate into increased earnings and consequently increased tax revenue for government. There are two fundamental economic relationships that underpin the analytic approach described here. Firstly, the established relationship between health and economic growth that is applicable to high, middle, and low income countries\textsuperscript{27}. Secondly, the known relationship between increasing economic growth and its influence on government tax revenues\textsuperscript{8}.

Deriving net tax revenues from health gains is an unconventional approach for valuing health gains seldom considered in the health economics literature. In contrast, valuing human lives in future tax revenue is fundamental to analytic approaches used by Treasury departments and international organisations such as the World Bank and IMF which often apply a generational accounting framework to analyse policy decisions\textsuperscript{15}. Inherent in these methodologies is the value of translating health capital into productive output and future tax revenue for government. The generational accounting framework is suitable for estimating this relationship because underlying the approach is demography and the current and future productive capacity of individuals.

At the core of generational accounting are population age-structure (i.e. demography), the proportions of people of working-aged populations, future workers in the case of children, and their future output. These core measures
are intricately linked to population health status and investments within the health sector. Consequently, it is possible to employ the generational accounting framework to determine how investments in health programs that influence the population age-structure and productivity will influence current and future government taxes and transfers. Furthermore, as implied by the name, the generational accounting framework assesses the fiscal dynamics of population health over very long time periods. In the context of low and middle income countries the framework demonstrates the benefits of immunisation and functional domestic tax systems that contribute to fiscal sustainability – a cornerstone in the development strategy.

The results described here demonstrate the long-term net tax benefits attributed to immunisation. Consistent with the previously published cost-effectiveness models for these countries, our fiscal models demonstrate a modest reduction in health cost savings attributed to reduced rotavirus morbidity\textsuperscript{16, 17}. In addition, over time as the immunised and non-immunised groups enter the work force the accumulated net tax benefits start to materialise. At the age of 33 and 43 in Ghana and Vietnam, respectively, the discounted net tax revenues for the immunised cohort are higher than the non-immunised. This is attributed to higher survival rates and therefore more tax payers, however because of transfers and immunisation in the early years of life a number of working years are required before these public investments are paid for through cumulative tax contributions.

Increasingly cost-effectiveness analysis is used to achieve technical efficiency when choosing between treatment alternatives. The limitation of cost-effectiveness is that it does not inform how investments in health influence economic growth – an important consideration regarding health expenditure in developing economies. The analysis described here pursues a different approach and uses fiscal accounting framework to understand how changes in rotavirus vaccine preventable cases will influence future government tax revenues and transfers. In this respect the method illuminates a pathway to fiscal sustainability associated with current decisions and the likely consequences in the future.

To some extent applying a fiscal perspective to medical technologies highlights the limitations of the societal perspective typically applied in cost-effectiveness analysis\textsuperscript{28}. Because the societal perspective excludes the economic consequences of health status changes for governments, the impact of health status changes on transfers and taxes would not be captured \textsuperscript{29}. Whilst the societal perspective is useful for reflecting societal welfare, the actuarial and fiscal consequences of changes in health status represent real
costs to governments that can be quantified\textsuperscript{1-3}. Because fiscal sustainability is increasingly on the agenda for both developed and developing economies, although for different reasons, the government perspective framework described here to some extent links investment in health with the sustainability agenda.

One limitation of the methodological framework described here is that not all low and middle income countries in need of immunisation have reliable and functional taxation systems. Applying the generational accounting approach to public investments in immunisation requires that morbidity and mortality can be translated into productivity, labour force participation and wage changes in order to describe the fiscal consequences for government. With respect to taxation systems in low and middle income countries, the approach described here is aligned with the taxation and development literature which views tax policy as a means to facilitate economic development through distribution of wealth, government accountability and moving towards achieving sustainability\textsuperscript{30}.

Life course modelling poses methodological challenges due to the necessity to make assumptions about long-term parameters that will change over time and influence modelled conclusions. Consistent with the generational accounting framework on which our methodology is based, we hold variables constant over time and test these assumptions using sensitivity analysis. The results described here are most sensitive to the discount rate and wages and productivity growth as depicted in Figure 3.1 and Figure 3.2. In light of the sensitivity of deriving long-term estimates linked with investments in healthcare, the results described here do not provide a precise forecast of the future. Rather, they reflect a potential fiscal scenario based on current epidemiological and macro-economic conditions and the interaction of these variables over time could give rise to variation reported here\textsuperscript{31}.

An additional limitation of the method is the size of the informal economy that exists in many low and middle income countries that would not be subject to taxation\textsuperscript{26}. The informal economy represents a serious limitation to any economic analysis investigating fiscal policy. However, it is worth noting that factors that drive the informal economy includes high tax burden, regulation and the prevailing economic conditions. In this respect the informal economy is not limited to low and middle income countries with the informal economy in some high income countries is as high as that found in Vietnam\textsuperscript{26}.

Beyond the academic approach for analysing the fiscal impact of changes in health, it is envisaged that this approach can inform future access decisions.
Funding decisions for vaccines are often made outside traditional health service decision-making bodies, and often at the ministerial level. With this in mind the modelling framework described here speaks to a different set of stakeholders who are important for releasing funds to pay for vaccines. Unlike cost-effectiveness analysis which often translates benefits into quality-adjusted life years (QALYs), the framework described here translates benefits into a language familiar to finance ministers and policy makers based on future net tax revenues linked to investing in health programs. In this respect the analysis described here should be considered complimentary to cost-effectiveness analysis as informs a different set of stakeholders.

References
22. USAID, Educational Quality Improvement Program: Meeting EFA. Cost-Effectiveness of Complementary Approaches. [http://www.equip123.net/docs/e2-MeetingEFA_WP.pdf].


