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PUBLIC HEALTH

The broad socioeconomic benefits of vaccination

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Evaluating vaccination programs according to their broad socioeconomic benefits, beyond their health benefits, will help to address the twin problems of vaccine underutilization and weak incentives for vaccine innovation.

Vaccination is among the most important public health innovations of all time. It saves 6 million lives each year, including those of 2.5 million children, and has eradicated smallpox and almost eradicated polio (*1*). It reduces infectious disease burden more effectively than any other public health strategy, with the possible exception of the provision of clean water. In the United States, the incidence of the nine diseases for which vaccination has been recommended the longest has declined by 95% (*2*).

Despite vaccination's proven track record, two global challenges persist: It remains underutilized relative to global recommendations, and incentives for vaccine innovation are relatively weak. These challenges are complex and defy single-factor explanations. Underutilization is driven by constrained budgets and competing public-sector priorities (for example, economic growth, poverty alleviation, and education), oligopolistic pricing (high prices reflecting few sellers), and vaccine hesitancy (the reluctance of individuals to get vaccinated or to have their children vaccinated, often due to mistrust or misinformation). Incentives to invest in vaccine research and development (R&D) are weak in part because of public-sector payers' exerting downward pressure on prices. Vaccine R&D is a fixed cost and global public good, and markets have well-known problems financing such investments adequately and equitably.

These challenges are related and can be in tension with each other. Reducing vaccine prices increases utilization but undermines innovation if prices fail to compensate firms for the costs and risks of R&D. Raising prices improves incentives but jeopardizes utilization and can regressively redistribute resources from global populations to the pharmaceutical industry. Reconciling utilization and incentives therefore requires balancing equity and efficiency goals.

Underlying both of these challenges is the narrow perspective typically taken by policymakers when measuring value-for-money to inform decisions about vaccination budgets.

Vaccination-relevant priority setting within a country occurs at two levels: within–health-sector priority setting and public-sector–wide priority setting. Within-health–sector priority setting takes the health sector's budget as given and allocates it across health interventions (for example, vaccines versus cancer treatments). An example of a decision at this level is funding pediatric vaccination against pneumococcal disease versus funding the construction of new community clinics. Such priority setting is typically the province of health ministries. Public-sector–wide priority setting determines the size of the health budget as a share of the overall public-sector budget (assumed, for simplicity, to be fixed in size). It sometimes considers line items in a specific sector's budget, like vaccination expenditures. It requires balancing all of society's competing priorities (like health, economic growth, equity, and education). This, in turn, requires assessing the relative value of qualitatively different public-sector outputs (for example, lowering under-five mortality rates versus raising primary school completion rates). An example of a decision at this level is expanding the national vaccination budget at the expense of the public works budget. Such decisions are typically the remit of finance ministries. Rational policy-makers at either level should set resource allocation priorities using normatively and scientifically defensible valuation frameworks. Two widely used frameworks are cost-effectiveness analysis from the health-sector perspective (CEA-H) and benefit-cost analysis (BCA).

COST-EFFECTIVENESS ANALYSIS FROM THE HEALTH SECTOR PERSPECTIVE

Suppose a finance ministry adheres to the following commonsense process: It ascertains society's relative preferences regarding social goods (for example, health, education, infrastructure, etc.), gives the health ministry a budget proportional to the strength of social preferences for health vis-à-vis non-health social goods, and delegates to the health ministry the task of producing as much health as possible given that budget. This process naturally lends itself to health ministries' setting their priorities on the basis of CEA-H. CEA-H takes the health budget as given and allocates it across competing interventions to maximize overall health gains per budget dollar spent. CEA-H measures individuals' overall health over some duration (such as a lifetime) as a weighted average of time spent in various health states, where the weights reflect individuals' relative preferences for the quality of life associated with those states. Overall health is commonly measured in quality-adjusted life years (QALYs). CEA-H tells the health ministry to prioritize interventions with low incremental cost-effectiveness ratios or budget dollars required per QALY produced. This maximizes society's QALY gain from the fixed budget. CEA-H is a narrow approach to vaccine evaluation because it focuses on only two effects of vaccination: QALYs and the health budget.

BENEFIT-COST ANALYSIS

For the past quarter century, health expenditures have increasingly been reconceptualized as not mere consumption of resources, but also as productive investments yielding broad socioeconomic benefits for individuals and societies. This newer view emphasizes the well-documented instrumental value of health in facilitating non-health aspects of individual and social well-being. Vaccines prevent physical and cognitive impairments, which improves educational outcomes and labor productivity. They reduce child mortality, which reduces precautionary fertility (*3*), and may, in turn, spur economic growth via a demographic dividend (*4*). Vaccines protect against the financial risks of illness such as out-of-pocket medical care costs and lost earnings. The productivity benefits of vaccines can manifest in higher growth rates of per capita gross domestic product (GDP) (*5*). Keeping people productive also yields fiscal benefits in terms of higher

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income- and expenditure-tax revenues and lower safety-net spending. Vaccines can produce disproportionate socioeconomic benefits for the poor, making vaccines potent tools for social equity. Vaccines help to keep the elderly healthy, independent, and productive, thereby reducing the socioeconomic risks of global population aging. Vaccines reduce the risks and scale of infectious disease outbreaks and of their consequent strains on health and public services. By reducing the need for antimicrobial therapy, vaccination counteracts the rise of antimicrobial resistance, which could cause up to 300 million premature deaths and 100 trillion dollars in lost GDP by 2050 if left unchecked (*6*). Finally, all of vaccination's broad health benefits are amplified through herd protection of the unvaccinated and also through any nonspecific disease prevention effects (*7*).

In theory, CEA-H accommodates some broad benefits because the QALY weights of different health states can incorporate individuals' preferences for the socioeconomic consequences of those states. For example, if people judge impaired mobility to pose a significant threat to their livelihoods, then QALY weights for health conditions that affect mobility may reflect this concern. Thus, CEA-H incorporates socioeconomic considerations to the extent that people internalize them in their relative valuation of different health states. In practice, however, survey methods for eliciting QALY weights do not convey to people the socioeconomic consequences of health states, which likely results in weights that only poorly reflect the real value to people of those consequences and that therefore understate the broad burden of those health states. Moreover, QALYs cannot reflect any broad externality benefits, that is, those benefits to the larger society that individuals do not take into account in their health state valuations.

The valuation framework that best implements the broad benefits view is BCA. When an intervention generates multiple benefits for an individual, that individual will have a monetary willingness to pay for those collective benefits. This equals the maximum the individual could pay for those benefits without making himself or herself worse off than before the intervention. It represents the dollar value to the individual of the intervention's broad benefits. The gross social benefits of the intervention are the sum across all individuals in society of this willingness to pay. The social rate of return to the intervention equals the ratio of its gross benefits to its gross costs (for example, the cost of vaccine delivery and administration, etc.), minus 1. This rate of return can be made sensitive to equity considerations by scaling people's willingness to pay to correct for differences in ability to pay between rich and poor and to reflect any priority society gives to benefitting the worse off. This social rate of return captures external benefits because anyone's willingness to pay for any downstream benefit counts even if that person is not the direct recipient of the vaccine or beneficiary of some other public-sector activity.

BCA monetizes benefits regardless of their natural units (for example, health-risk reductions, years of schooling, miles of roads, etc.), so returns can be compared across health and non-health interventions (for example, vaccines versus fuel subsidies), all of which, in principle, can have broad benefits that ought to be compared. Thus, BCA can be used in both cross-sector and within-sector policymaking. Within the health sector, the health minister could prioritize health interventions based on their relative social rates of return. At the cross-sector level, the finance minister could allow the health budget to grow or shrink depending on how well the returns to health interventions such as vaccination compare with those of non-health interventions.

By enabling comparisons of interventions across sectors, BCA enables more efficient allocation of resources in accordance with social preferences. Efficient allocation may sometimes involve channeling health-sector resources to the production of non-health social goods or non-health resources to the promotion of health outcomes. For example, it is plausible that national immunization programs have stronger impacts on school completion in some contexts than do some forms of educational intervention, such as computerized learning. Similarly, some forms of educational intervention, such as compulsory schooling, could have a larger impact on population life expectancy (by raising income and allowing people to afford healthier lifestyles) than some health interventions, such as organ replacement. Maximal fulfillment of social preferences for the goods produced by the public sector is facilitated by valuing goods uniformly across sectors (according to people's willingness to pay for them) and by rate-of-return–guided priority setting (which maximizes the social value of the aggregate goods produced from public-sector expenditure).

Some see the monetization of health benefits required for BCA as morally objectionable. But such monetization is unavoidable and routinely done, often implicitly. In our private lives, we must decide how much to spend on safety equipment (for example, safety devices in cars and homes). A nationalized health insurance program requires society to decide how heavy a tax burden to impose to finance health care. A market-based health insurance system requires individuals to trade off premiums versus service coverage. Failure to rationally trade off money for health results in unnecessary mortality and morbidity and their social and economic sequelae.

CEA-H VERSUS BCA

So, which analytical approach to priority setting (and which corresponding tool) is superior? CEA-H has the advantage of simplicity. It ignores the socioeconomic values external to QALYs and the health system, and so avoids the empirical challenges of measuring them and the decision-making challenges of taking them into account in setting priorities. It also avoids some ethically contentious implications of BCA, such as giving priority to more productive individuals. But BCA has the advantage of efficiency, that is, the maximal fulfillment of society's preferences for the various social goods produced by the public sector, including the various socioeconomic benefits produced by health-sector programs, such as vaccination. BCA also can be extended to incorporate equity considerations, for example, by giving greater weight to the willingness to pay of the worse-off, without denying the obvious relevance of productivity.

Given that equity concerns can be fully addressed in extensions to BCA, the choice between CEA-H and BCA depends largely on the relative value of simplicity and efficiency. We believe that the value of efficiency clearly trumps the value of simplicity, and therefore BCA trumps CEA-H. The monetary value of vaccination's broad benefits, for example, is potentially in the billions of dollars and large enough to express in terms of fractions of GDP, whereas the costs of measuring them and considering them in decision-making are likely to be trivial in comparison.

Recent empirical studies informed by the broad benefits perspective demonstrate this approach's feasibility and empirical relevance. A study of the *Haemophilus influenzae* type b vaccine showed that whether its benefit-cost ratio exceeds 1 depends on including its broad benefits (*8*). The impact of maternal tetanus vaccination on children's educational attainment in Matlab, Bangladesh, was estimated

to compare favorably to that of other educational investments (*9*). The return from investments made by Gavi, the Vaccine Alliance, to boost coverage of new and underused children's vaccinations in low-income countries was estimated to compare favorably to returns from schooling (*10*), a widely accepted "best buy" in development expenditures. Society suffers considerably when vaccination is underutilized as a result of an underappreciation of its broad socioeconomic benefits.

The choice between narrow CEA-H–based and broad BCA-based perspectives is of significance to the twin challenges of utilization and incentives. The narrow perspective of CEA-H undervalues vaccines and can lead to underutilization by policy-makers, resulting in lower socioeconomic well-being among the populace. This underutilization lowers profits, reducing the incentive for manufacturers to innovate. A fuller picture of the broad benefits of vaccination can lead policy-makers and global donors to expand vaccine expenditures, which, in turn, supports profits and innovation.

CONCLUSIONS

Further questions that deserve to be addressed include the following. Do broad benefits flow from other health technologies or even non-health policies that compete with vaccine expenditures? If everything has broad benefits, do they just cancel out in judgments of relative priority? Why believe that vaccines specifically are undervalued?

Many high-impact non-health policies are already understood in investment terms and therefore are evaluated in terms of their socioeconomic benefits (such as the effects of education on productivity and earnings), so the broad benefits argument applies particularly to health technologies that have traditionally been understood in consumption terms.

CEA-H may be especially poor at handling the broad benefits of interventions against infectious diseases, which offer greater externality benefits than interventions against noncommunicable diseases. Vaccination is more effective at reducing infectious disease burden than almost any other public health strategy. Vaccines have near unrivaled scope among health technologies in terms of the number of diseases they can address, the stages of the human life cycle upon which they confer benefits, the sheer number of potential beneficiaries worldwide, and the potential for disease eradication, elimination, and control. Their disproportionate capacity to affect population-level health suggests a disproportionate capacity to produce externalized broad benefits. By contrast, the benefits of interventions against noncommunicable diseases, such as cancer and heart disease, will be reasonably well captured in a narrow perspective, insofar as noncommunicable diseases are likely to have less impact on people's ability to work (given that these diseases tend to affect people later in life) and have no impact on future incidence. Although competing health and non-health technologies would ideally be evaluated in light of their broad benefits, there is reason to believe that the broad benefits of vaccines may be disproportionately important.

Adoption of a more relevant framework for assessing vaccines is necessary but not sufficient for better addressing the twin challenges of underutilization and weak incentives. The global community must also address other issues, such as tight budgets, vaccine pricing and market failures, vaccine hesitancy abetted by misinformation, whether to adopt alternative financing mechanisms such as prizes and advanced market commitments, and the balancing of equity and efficiency goals. Nevertheless, a superior valuation framework remains an important element of an overall strategy. Indeed, such a framework can inform efforts to address these other issues. It can strengthen social marketing and information campaigns to combat vaccine hesitancy by showing the underappreciated links between vaccination and people's everyday socioeconomic concerns. It can clarify whether any particular vaccine price reflects an appropriate balance of utilization and incentive goals. Finally, it can help to justify the efforts of global organizations, such as the recently established Coalition for Epidemic Preparedness Innovations, and provide an appropriate and actionable tool to guide their decision-making.

REFERENCES AND NOTES

1. World Health Organization, UNICEF, World Bank, *State of the World's Vaccines and Immunization* (World Health Organization, Geneva, ed. 3, 2009).
2. Centers for Disease Control and Prevention (CDC), Impact of vaccines universally recommended for children—United States, 1900–1998. *MMWR Morb. Mortal. Wkly. Rep.* **48**, 243–248 (1999).
3. L. Angeles, Demographic transitions: Analyzing the effects of mortality on fertility. *J. Popul. Econ.* **23**, 99–120 (2010).
4. UNFPA EECA, *State of World Population 2014: The Power of 1.8 Billion* (United Nations Population Fund, New York, 2014).
5. N. A. Masia, J. Smerling, T. Kapfidze, R. Manning, M. Showalter, Vaccination and GDP growth rates: Exploring the links in a conditional convergence framework. *World Dev.* **103**, 88–99 (2018).
6. *Antimicrobial Resistance: Tackling a Crisis for the Health and Wealth of Nations* (Review on Antimicrobial Resistance, December 2014, chaired by Jim O'Neill).
7. M. J. Mina, Measles, immune suppression and vaccination: Direct and indirect nonspecific vaccine benefits. *J. Infect.* **74**, S10–S17 (2017).
8. T. Bärnighausen, D. E. Bloom, D. Canning, A. Friedman, O. S. Levine, J. O'Brien, L. Privor-Dumm, D. Walker, Rethinking the benefits and costs of childhood vaccination: The example of *Haemophilus influenzae* type b vaccine. *Vaccine* **29**, 22371–22380 (2011).
9. D. Canning, A. Razzaque, J. Driessen, D. G. Walker, P. K. Streatfield, M. Yunus, The effect of maternal tetanus immunization on schooling attainment in Matlab, Bangladesh: Follow-up of a randomized trial. *Soc. Sci. Med.* **72**, 1429–1436 (2011).
10. D. E. Bloom, D. Canning, M. Weston, The value of vaccination. *World Econ.* **6**, 15–39 (2005).

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Abstract

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