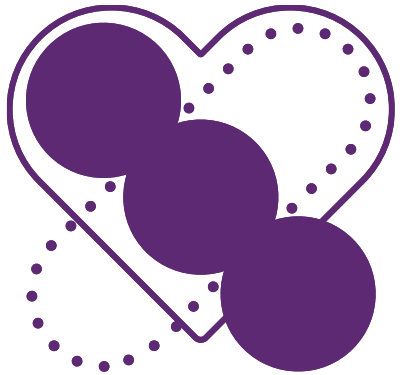
The full health, economic, and social benefits of vaccination: conceptual framework and application to Strep A vaccines



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From healthier means wealthier to the value of vaccination

SCIENCE'S COMPASS • POLICY FORUM

POLICY FORUM: PUBLIC HEALTH

The Health and Wealth of Nations

David E. Bloom* and David Canning

The positive correlation between health and income per capita is one of the best-known relations in international development (see figure). This correlation is commonly thought to reflect a causal link running from income to health. Higher income gives greater command over many of the goods and services that promote health, such as better nutrition and access to safe water, sanitation, and good quality health services.

Recently, however, another intriguing possibility has emerged: that the health-income correlation is partly explained by a causal link running the other way—from health to income. Several mechanisms, falling into four main categories, could account for this relation:

Productivity. Healthier populations tend to have higher labor productivity, because their workers are physically more energetic and mentally more robust. They suffer fewer lost workdays from illness or the need to care for other family members who have fallen ill.

Education. Healthier people who live longer have stronger incentives to invest in developing their skills, because they expect to reap the benefits of such investments over longer periods. Increased schooling promotes greater productivity and, in turn, higher income. Good health also promotes school attendance and enhances cognitive function.

Investment in physical capital. Improvements in longevity create a greater need for people to save for their retirement. Insofar as increased savings lead to increased investment, workers will have access to more capital and their incomes will rise. In addition, a healthy and educated workforce acts as a strong magnet for foreign investment.

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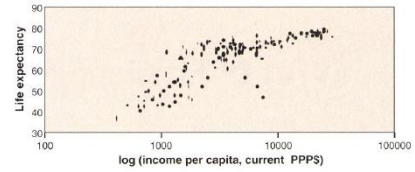
"Demographic dividend." The transition from high to low rates of mortality and fertility has been dramatic and rapid in many developing countries in recent decades. Mortality declines concentrated among infants and children typically initiate the transition and trigger subsequent declines in fertility. An initial surge in the numbers of young dependents gradually gives way to an increase in the proportion of the population that is of working age (*1*). As this happens, income per capita can rise dramatically, provided the broader policy environment permits the new workers to be absorbed into productive employment (*2*).



Life expectancy and income in purchasing power parity (PPP) dollars, 1997. [Source: World Bank (*14*)]

All these mechanisms offer plausible ways in which health improvements can lead to income growth. However, examining the data allows evaluation of how important these mechanisms are. Recent economic analysis indicates that health status (as measured by life expectancy) is a significant predictor of subsequent economic growth (*3*). This effect is above and beyond other influences on economic growth, emerges consistently across studies, and is strikingly large (*4*).

Suppose we compare two countries that are identical in all respects, except one has a 5-year advantage in life expectancy. On the basis of studies in several countries, real income per capita in the healthier country will grow 0.3 to 0.5% per year faster than in its less healthy counterpart. This represents a sizable boost to growth, given that, from 1965 to 1990, countries experienced an average per capita income growth of only 2% per year. Moreover, a gain of 5 years in life expectancy is well within the reach of most developing countries—since 1950, for example, life expectancy worldwide has increased by about 20 years.

As these health improvements fortify the economy, they also alleviate poverty. Economic growth is an exceedingly powerful way to reduce poverty among the 1.3 billion people living on less than US$1 per day. Available evidence indicates that increases in average income translate—percentage point for percentage point—into increases in the income of the poor. In addition, health improvements are disproportionately beneficial for the poor, as they depend on their labor power more than any other segment of the population.

Just as the direct effects of life expectancy on economic growth are important, so too are the indirect effects of improvements in health status that operate via demographic change. In East Asia, for example, the working-age population grew several times faster than the dependent population between 1965 and 1990. The whole process seems to have been triggered by declining child and infant mortality, itself prompted by the development of antibiotics and antimicrobials (such as penicillin, sulfa drugs, streptomycin, bacitracin, chloroquine, and tetracycline, all of which were discovered and introduced in the 1920s, 1930s, and 1940s), the use of DDT (which became available in 1943), and classic public health improvements related to safe water and sanitation (*5*, *6*). Health improvements can therefore be seen to be one of the major pillars upon which East Asia's phenomenal economic achievements were based, with the demographic dividend accounting for perhaps one-third of its "economic miracle" (*5*, *7*).

By contrast, poor health can slow the demographic transition and inhibit growth. In Sub-Saharan Africa, for example, a seemingly intractable disease burden induces many families to dissipate their resources among large numbers of children, creating a high-fertility, high-mortality poverty trap that impedes economic growth (*8*).

Patterns of energy use also mediate the interactions between health, demography, and income. The rural poor rely heavily on wood, dung, and other biomass. The resulting smoke and particulates are detrimental to human health and can diminish people's productivity. Across countries,

The Value of Vaccination

David E. Bloom, David Canning & Mark Weston

Introduction

> "You let a doctor take a dainty, helpless baby, and put that stuff from a cow, which has been scratched and had dirt rubbed into her wound, into that child. Even, the Jennerians now admit that infant vaccination spreads disease among children. More mites die from vaccination than from the disease they are supposed to be inoculated against." (George Bernard Shaw, 1929)

The world has come a long way since George Bernard Shaw fulminated against vaccination in the 1920s. Vaccines are now widely regarded as an effective and cheap tool for improving health. Children in all countries are routinely immunized against major diseases, and the practice has become a central plank of global public health efforts.

Despite these advances, however, immunization coverage remains far from universal, and the developing world in particular remains vulnerable to vaccine-preventable illnesses. For example, global coverage for DTP—the vaccine for diphtheria, tetanus, and pertussis (whooping cough)—had reached 70 per cent in the 1990s, but in sub-Saharan Africa it stood at just 53 per cent. In Somalia, Nigeria, and Congo, moreover, coverage halved between 1990 and 2000.[1] Vaccination against measles also falls short; the

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[1] World Health Organization (2002): "State of the World's Vaccines and Immunization 2002", WHO, Geneva.

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Bärnighausen et al. 2008

Perspective		Benefit categories
Broad	Narrow	Healthcare cost savings
		Health gains
		Care-related productivity gains
		Outcome-related productivity gains
		Behavior-related output gains
		Community externalities

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Bloom et al. 2017

Perspective		Benefit categories
Broad	Narrow	Healthcare cost savings
		Health gains
		Care-related productivity gains
		Outcome-related productivity gains
		Behavior-related output gains
		Health-based community externalities
		Co-morbidities
		Nosocomial infections
		Risk reduction gains
		Social equity

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Jit et al. 2015

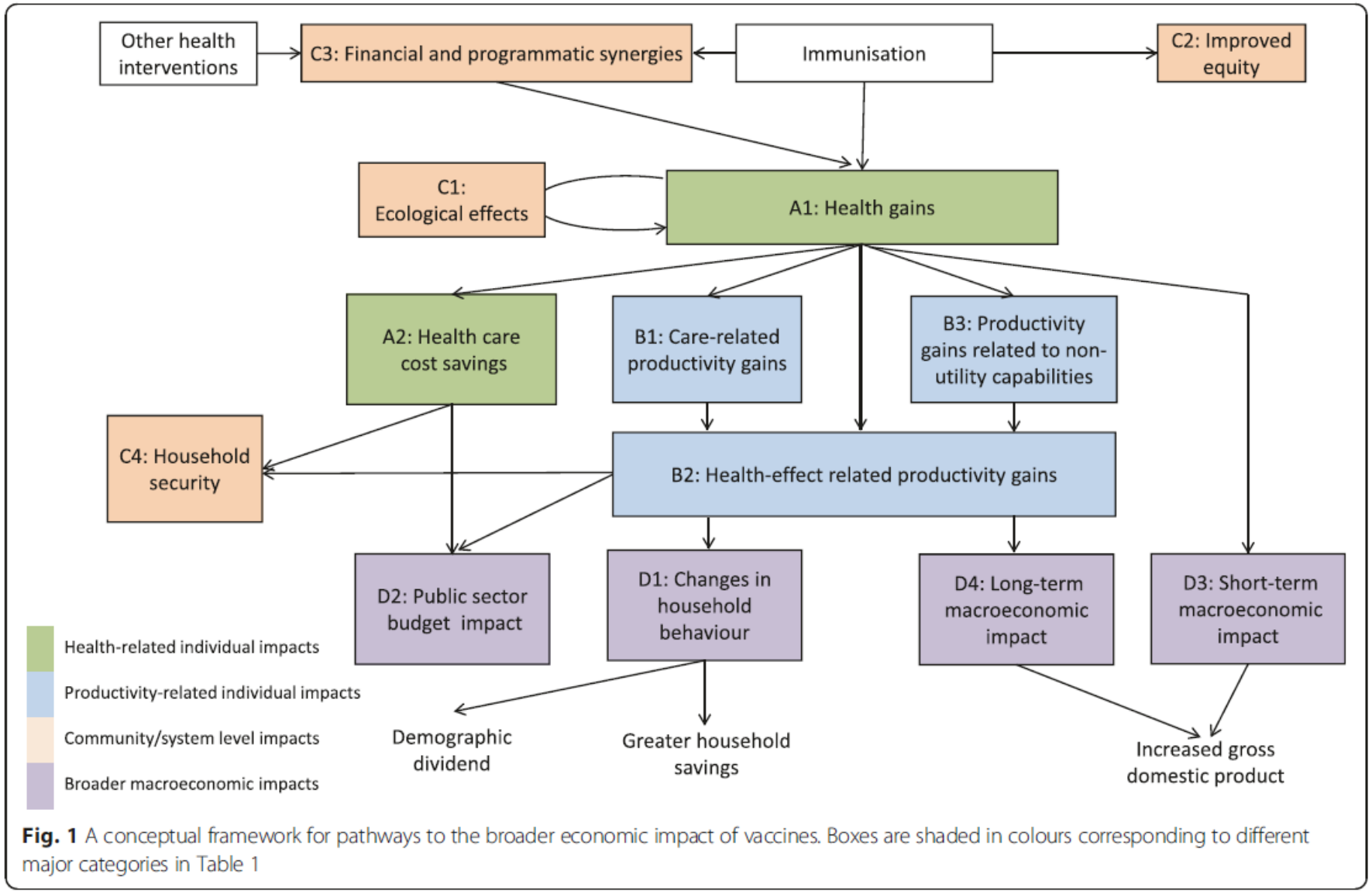

Fig. 1 A conceptual framework for pathways to the broader economic impact of vaccines. Boxes are shaded in colours corresponding to different major categories in Table 1

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Jit et al. 2015 – another view

	Benefit Category			
	A. Health-related benefits to vaccinated individuals	**B. Productivity-related benefits**	**C. Community or health systems externalities**	**D. Broader economic indicators**
Sub-category	Health gains	Productivity gains related to care	Ecological effects	Changes to household behavior
	Health care cost savings	Productivity gains related to health effects	Equity	Public sector budget impact
		Productivity gains related to non-utility capabilities	Financial and programmatic synergies and sustainability	Short-term macroeconomic impact
			Household security	Long-term macroeconomic impact

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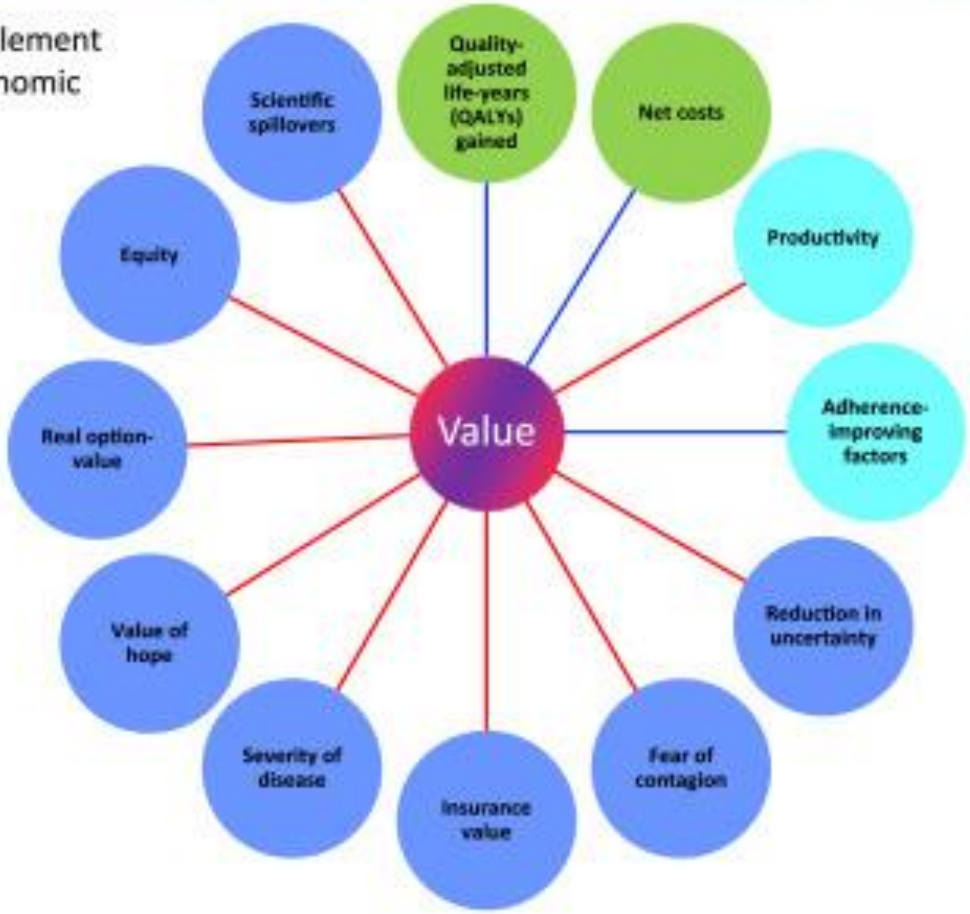
Mauskopf et al. 2018

Category	Factors
Narrow	• Avoidance of cases or events • Shift of severe to less severe cases or events • Reduction in medical resource use for those who are vaccinated • Increased productivity for those who are vaccinated and their families
Broad	***Positive*** • Herd protection • Reduced antimicrobial resistance • Improved capabilities (e.g., education, learning, and work) • Protection of households from catastrophic health expenditures • Improvement in quality of health care • Macroeconomic benefits (e.g., increased foreign investment and economic output throughout the economy) ***Positive or Negative*** • Age shifting of the infection and disease condition • Serotype replacement • Changes in health-related behaviors (e.g., those pertaining to risk exposure)

Lakdawalla et al. 2018

Elements of Value

Challenge: Map each element into an underlying economic framework for value assessment.



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Health, economic, and social benefits of vaccination and their distribution

	Vaccination benefits	Distribution			
		Individual	Family/ household	Society (health sector)	Society (general)
Health benefits	Direct health effects • Reduced morbidity & mortality due to target pathogen • Adverse effects of vaccination (negative benefit)	✓			
	Prevention of secondary individual (physical) health effects • Off-target pathogens • Aggravation of comorbidities • Nosocomial infections • Microbiome disruption	✓			
	Mitigation of secondary population-level health effects • Disease transmission • Antimicrobial resistance • Healthcare congestion			✓	✓
	Improved mental health	✓	✓		
Economic benefits	Reduced healthcare costs	✓	✓	✓	
	Reduced caregiving costs	✓	✓	✓	
	Reduced transportation costs	✓	✓		
	Increased labor force participation, hours worked, and income Increase in productive non-market activities	✓	✓		✓
	Improved educational attainment, school attendance, and cognition	✓			✓
	Fiscal impact • Increased tax receipts • Reduced public health spending			✓	✓
	Increased wealth/savings	✓	✓		
	Reduced risk and severity of impoverishment	✓	✓		✓
	Reduced risk of economically disruptive outbreaks			✓	✓
Social benefits	Improved social equity				✓
	Intergenerational benefits		✓		
	General risk reduction	✓	✓	✓	✓
	Improved quality of life	✓	✓		✓
	Reduced stigma	✓	✓	✓	✓

Health benefits of Strep A vaccination

	Vaccination benefits	Distribution: Individual	Distribution: Family/ household	Distribution: Society (health sector)	Distribution: Society (general)
Health benefits	Direct health effects • Reduced morbidity & mortality due to target pathogen • Adverse effects of vaccination (negative benefit)	✓			
	Prevention of secondary individual (physical) health effects • Off-target pathogens • Aggravation of comorbidities • Nosocomial infections • **Microbiome disruption**	✓			
	Mitigation of secondary population-level health effects • Disease transmission • **Antimicrobial resistance** • Healthcare congestion			✓	✓
	Improved mental health	✓	✓		

Incorporating AMR into economic evaluation

SPECIAL FEATURE: PERSPECTIVE

Toward economic evaluation of the value of vaccines and other health technologies in addressing AMR

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We discuss the need to make economic evaluations of vaccines antimicrobial resistance (AMR)-sensitive and ways to do so. Such AMR-sensitive evaluations can play a role in value-for-money comparisons of different vaccines within a national immunization program, or in comparisons of vaccine-centric and non-vaccine-centric technologies within an anti-AMR program. In general terms, incremental cost-effectiveness ratios and rates of return and their associated decision rules are unaltered by consideration of AMR-related value. The decision metrics need to have their various health, cost, and socioeconomic terms disaggregated into resistance-related subcategories, which in turn have to be measured carefully before they are reaggregated. The fundamental scientific challenges lie primarily in quantifying the causal impact of health technologies on resistance-related health outcomes, and secondarily in ascertaining the economic value of those outcomes. We emphasize the importance of evaluating vaccines in the context of other potentially complementary and substitutable nonvaccine technologies. Complementarity implies that optimal spending on each set of interventions is positive, and substitutability implies that the ratio of spending will depend on relative value for money. We exemplify this general point through a qualitative discussion of the complementarities and (especially the) substitutability between pneumococcal conjugate vaccines and antimicrobial stewardship and between research and development (R&D) of a gonorrhea vaccine versus R&D of a gonorrhea antibiotic. We propose a roadmap for future work, which includes quantifying the causal effects of vaccination and other health technologies on short-term and long-term resistance-related outcomes, measuring the health-sector costs and broader socioeconomic consequences of resistance-related mortality and morbidity, and evaluating vaccines in the context of nonvaccine complements and substitutes.

antimicrobial resistance | vaccines | economic evaluation | health technology assessment | immunization

Antimicrobial resistance (AMR) is a significant emerging threat to global health and economic well-being. Despite the growing awareness of vaccines' contributions to addressing AMR, economic evaluations of vaccines by health and finance ministries, by global donors, and by the research community have so far insufficiently incorporated that AMR-related value (AMR value). Vaccines therefore remain at real risk of undervaluation and underinvestment in the allocation of AMR-earmarked health sector, public sector, and research and development (R&D) budgets.

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Economic benefits of Strep A vaccination

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Economic benefits	Reduced healthcare costs	✓	✓	✓	
	Reduced caregiving costs	✓	✓	✓	
	Reduced transportation costs	✓	✓		
	Increased labor force participation, hours worked, and income Increase in productive non-market activities	✓	✓		✓
	Improved educational attainment, school attendance, and cognition	✓			✓
	Fiscal impact • Increased tax receipts • Reduced public health spending			✓	✓
	Increased wealth/savings	✓	✓		
	Reduced risk and severity of impoverishment	✓	✓		✓
	Reduced risk of economically disruptive outbreaks			✓	✓

Social benefits of Strep A vaccination

	Vaccination benefits	Distribution			
		Individual	Family/ household	Society (health sector)	Society (general)
Social benefits	**Improved social equity**				✓
	Intergenerational benefits		✓		
	General risk reduction	✓	✓	✓	✓
	Improved quality of life	✓	✓		✓
	Reduced stigma	✓	✓	✓	✓

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Additional considerations for Strep A

- **Prospective valuation**
- **Multiple clinical endpoints**
- **Availability of alternative remedies (e.g., effective treatment)**
- **Potential for adverse outcomes**
  - Vaccine hesitancy

Thank you!

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