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MEDICINE AND ECONOMICS

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While remarkable gains in health have been achieved since the mid-20th century, these have been unequally distributed, and mortality and morbidity burdens in some regions remain enormous. Of the almost 10 million children under 5 years of age who died in 2006, only 100 000 died in industrialised countries, while 4.8 million died in sub-Saharan Africa.[1] In deciding whether to finance an intervention, policy makers commonly weigh the expected population health gains against its costs. Most vaccinations included in national immunisation schedules are inexpensive[2] and health gains to costs are very favourable compared with other health interventions. Newer vaccinations, such as those with pneumococcal conjugate vaccine (PCV) or rotavirus vaccine, are also effective in averting child mortality and morbidity but are expensive relative to those commonly included in national immunisation schedules. Policy makers may therefore decide that – at current prices – the comparison of health gains with costs does not justify the free public provision of these vaccinations. We argue that in addition to the health benefits of vaccinations, their effects on education and income[3] and benefits for unvaccinated community members are considerable and should be included in calculations to establish their value.

**Table I. Types of benefits in economic evaluations of vaccinations**

<table>
<tr><th colspan="2">Perspective</th><th>Type of benefit</th><th>Definition</th></tr>
<tr><td rowspan="6">Broad</td><td rowspan="3">Narrow</td><td>Health gains</td><td>Reduction in morbidity and mortality through vaccination</td></tr>
<tr><td>Health care cost savings</td><td>Savings of medical expenditures because vaccination prevents illness episodes</td></tr>
<tr><td>Care-related productivity gains</td><td>Savings of parents’ productive time because vaccination avoids the need for taking care of a sick child</td></tr>
<tr><td rowspan="3"></td><td>Outcome-related productivity gains</td><td>Increased productivity because vaccination improves cognition, physical strength, and school attainment</td></tr>
<tr><td>Behaviour-related productivity gains</td><td>Benefits accruing because vaccination improves child health and survival and thereby changes household behaviour</td></tr>
<tr><td>Community externalities</td><td>Benefits accruing because vaccination improves outcomes in unvaccinated community members</td></tr>
</table>

Most economic evaluations of vaccinations focus heavily on the benefits of avoided health care costs (Table I). While it is theoretically possible to take productivity gains into account in economic evaluation (Table II), traditionally, evaluations of vaccinations have either not considered such gains or have only included one particular type of gain: the value of the time that parents would have spent caring for a sick child had a disease episode not been averted by vaccination (care-related productivity gains, Table I).[4] Such a narrow perspective may lead to substantial underestimates of the value of some vaccinations. It neglects lifetime productivity gains because a vaccination prevents cognitive impairment, physical handicap, or low school attainment (outcome-related productivity gains, Table I). Vaccinations may influence educational attainment by preventing diseases that reduce school attendance or lead to impaired cognitive development. Cost-benefit analyses (CBAs) in developing countries find return on investment in vaccinations (due to improved cognitive development and worker productivity)[5] of similar magnitude to the return on investment in schooling.[6]

A narrow focus on care-related productivity gains excludes increases in productivity due to changes in behaviour in response to vaccination effects (behaviour-related productivity gains, Table I). Many vaccinations significantly reduce child mortality from infectious diseases, and as this declines, parents can give birth to fewer children to attain their desired minimum number of offspring.[7] Such a fertility choice improves economic productivity. Declining fertility leads to a decreasing ratio of economically dependent people in a population, which increases the labour force per capita and savings. Savings can be invested in the physical and human capital needed for economic growth. As fertility declines and average family size decreases, parents are likely to invest more in the education and health of each child, leading to improved productivity when they enter the labour market.

Most economic evaluations of vaccinations also do not consider the value of externalities in the wider community, i.e. the effect of a child's vaccination on non-vaccinated community members. These include decreases in infection rates in unvaccinated people because vaccinations reduce the probability that a healthy individual will encounter an infectious person (up to the point of herd immunity, where sufficient numbers of people are vaccinated such that infection of one individual will not result in an epidemic) (Table I). Rates of antibiotic resistance also decrease because less antibiotics are used when more children are protected by vaccination against bacterial infections.

**Table II. Types of economic evaluations**

| Term | Definition |
|---|---|
| Cost-effectiveness analysis (CEA) | Comparison of the health effectiveness of an intervention (measured in a common unit, e.g. quality-adjusted life years) to its costs (measured in money units)<br><br>Productivity gains and externalities can be taken into account as cost reductions |
| Cost-benefit analysis (CBA) | Comparison of the benefits and costs of an intervention (both measured in money units that are discounted to the same time frame)<br><br>Productivity gains and externalities can be taken into account as benefit increases (or cost reductions) |

**Applying the broad perspective to value of vaccination in South Africa**

Taking a broad perspective may be especially important in evaluating vaccinations in South Africa (Table I). From 1976 to 2006, the proportion of the South African population younger than 15 years of age fell from 42% to 32%[8] as fertility declined,[9] in part the result of HIV-related infertility and foetal loss,[10] while working age adults increased (the fraction of people age 65 years and above remained approximately constant).[8] When the ratio of children and elderly per working-age adult decreases, a country has an opportunity to develop economically and increase productivity because investment in physical and human capital will increase.[7]

Health is an important form of human capital, including that attained through vaccinations. South Africa has made great strides in increasing coverage of basic childhood immunisation. The *South African Demographic and Health Survey* in reported coverage with routine vaccines in children 12 - 23 months of age ranging from 65% for poliomyelitis vaccine (polio3) to 81% for Bacillus Calmette-Guérin vaccine (BCG) in 2003.[11]

Vaccinations have contributed significantly to South Africa's decline in child mortality. From 1975 to 1990, under-5 mortality declined by almost half, from 110 to 60 deaths per

1 000 live births.[9] However, this trend has been reversed recently, largely because of the HIV epidemic.[12] The under-5 mortality rate in South Africa was 69 per 1 000 live births in 2006[11] and is therefore not on target to achieving the UN's Millennium Development Goal of reducing under-5 mortality by two-thirds between 1990 and 2015.

Many interventions that could reduce child mortality in South Africa – such as improved access to safe water and sanitation, improved childhood nutrition, or poverty reduction – require large infrastructure investment or sustained changes in social policy. The noteworthy decision by the South African Department of Health to add PCV and rotavirus vaccination to the national immunisation schedule, despite their comparatively high prices,[13] may therefore serve as a stimulus for other countries to follow.

Pneumococcal diseases are a major cause of childhood mortality and morbidity in South Africa.[14] PCV is effective in preventing pneumococcal diseases, including pneumonia, meningitis, and otitis media. (While we describe productivity gains and externalities using the example of PCV vaccination, a similar case of substantial vaccination benefits can be made for the rotavirus vaccine.) Because HIV-infected children are at significantly higher risk of acquiring pneumococcal disease than uninfected children, PCV will prevent larger numbers of pneumococcal infections and deaths in HIV-infected children, even though they are less likely to develop a protective immune reaction in response to PCV than HIV-uninfected children.[15] A large randomised controlled trial in South Africa found that PCV prevented 267 and 2 573 cases of pneumococcal pneumonia per 100 000 person-years in HIV-uninfected and HIV-infected children, respectively.[14] PCV vaccination is therefore an appropriate intervention to mitigate the negative effect of HIV on child mortality. In addition to its health benefits, PCV coverage may lead to behaviour-related productivity gains, if the mortality reduction due to vaccination accelerates South Africa's current fertility decline.

PCV is further likely to lead to considerable outcome-related productivity gains. First, episodes of pneumococcal pneumonia will keep children, especially those who are HIV-infected, out of school for substantial periods of time, preventing cognitive development and learning.[16] Second, survivors of pneumococcal meningitis frequently suffer from severe cognitive and neurological sequelae; a study in The Gambia found that 58% of children who had survived a bout of pneumococcal meningitis 'had clinical sequelae; half of them had major disabilities preventing normal adaptation to social life', such as mental retardation, hearing loss, motor abnormalities, and seizures.[17] Third, pneumococcal otitis media can impair cognitive development; a study in the USA found that time spent with middle ear effusion during the first 3 years of life was significantly associated with lower scores on tests of cognitive ability, speech and language, and lower school performance at age 7 years.[18] Fourth, pneumococcal otitis media leads to hearing loss in a substantial proportion of affected children.[19] While hearing-impaired children in developed countries receive specialised support necessary to attain educational levels on par with non-deaf children, such systems are lacking in many developing countries.[20]

Moreover, PCV coverage is likely to benefit unvaccinated community members. It decreases the rate of occurrence of antibiotic-resistant pneumococcal infections,[21] avoiding the health costs of untreatable disease or costs of using more expensive second-line antibiotics. As pneumococcal disease can cause substantial morbidity and mortality in the elderly and in the HIV-infected middle-aged, childhood PCV vaccination is likely to lead to substantial reduction in pneumococcal disease burden in those not routinely receiving the vaccination. A study in the USA taking such herd effects into account found large benefits from the externality,[22] but most other studies of PCV value have ignored them.[23] Herd protection against pneumococcal disease may be especially important in South Africa, where a large proportion of the adult population is HIV-positive and therefore vulnerable to severe recurrent pneumococcal infections.

## Conclusions

South Africa has proven its commitment to ensuring that children receive effective vaccines, attaining high national vaccination coverage levels. In 2006 the country pledged $20 million to the International Finance Facility for Immunization (IFFIm), the major source of finance for the GAVI Alliance’s effort to extend coverage with new and underused vaccines to low-income countries,[24] and more recently decided to include PCV and rotavirus vaccine in its national immunisation schedule.[25] Coverage of children with the two vaccines will be likely to lead to substantial health gains.

It is highly likely that such coverage will have significant productivity gains, contributing to South Africa’s economic development, and benefit unvaccinated South Africans. The precise size of the contributions of these productivity gains and externalities to health and wealth in South Africa are unknown. Adding the two vaccinations to the national immunisation schedule offers an excellent opportunity to measure these effects, and evaluation studies should complement the vaccination roll-out. As the evidence grows, we expect the estimates of the value of many vaccinations to increase significantly, ensuring that policy makers have the necessary information to make optimal choices on vaccination provision.

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