

THE COST OF QUALITY IMPROVEMENTS DUE TO INTEGRATED MANAGEMENT OF CHILDHOOD ILLNESS (IMCI) IN UGANDA

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SUMMARY

The goal of this paper is to measure the marginal change in facility-level costs of medical care for children under five due to an increase in service quality achieved through the integrated management of childhood illness (IMCI) strategy. Since the beneficial effects of IMCI training on child health outcomes are due to IMCI's effects on service quality, costs of IMCI are regressed against measures of service quality in this paper. Our model shows that quality, as measured by a WHO-index of integrated child assessment is 44% higher in facilities with at least one health worker trained in IMCI as compared to facilities with no health workers trained in IMCI, adjusting for facility utilization as well as type of facility ownership. Our marginal analysis that tied IMCI training to quality and quality to costs shows that on the margin, investing in IMCI training at a primary facility level can yield a significant 44.3% improvement in service quality for a modest 13.5% increase in annual facility costs. Copyright © 2007 John Wiley & Sons, Ltd.

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INTRODUCTION

Integrated Management of Childhood Illness (IMCI) was developed by UNICEF and WHO as a strategy for reducing mortality among children under the age of 5 in developing countries (Tulloch, 1999). The full model of IMCI aspired to achieve training of health workers, health system improvements and community/family interventions. However, systematic evaluation has revealed that IMCI programs have succeeded primarily in achieving health worker training, leaving health system and community/family interventions unimplemented or weak (Bryce *et al.*, 2005b). Thus, despite its greater potential, IMCI in practice has remained primarily a strategy for health service quality improvement by training health workers to use case management guidelines. The IMCI clinical guidelines improve diagnosis, treatment, and the identification of critically ill children for whom immediate hospital referral may be lifesaving (Kolstad *et al.*, 1998). The guidelines help clinicians to pay closer attention to the physical examination of children, to prescribe drugs more rationally, and to counsel parents in caring for sick children. IMCI has been shown to increase the time providers spend

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with children (Adam *et al.*, 2005a) and may also decrease both the treatment cost of medication as well as the percent of inappropriate referrals to hospitals (Kolstad *et al.*, 1998).

The IMCI guidelines have now been adopted by more than 100 countries (World Health Organization, 2005). When a country 'adopts' IMCI its ministry of health tailors pre-existing WHO guidelines to its local health system, prepares training materials, develops trainers, and then launches a campaign to deliver training sessions to the thousands of clinical staff in the health system. Given that most of the IMCI 'adoption' decisions have already occurred all around the world, the key policy question surrounds the costs and benefits of sustaining and scaling up IMCI training. At the margin the question centers on what will be the cost and benefit of converting one more clinician or one more dispensary from standard practice to IMCI. We will now review what is known about the costs and benefits that attend a decision to phase in IMCI at the facility or district level.

Because IMCI alters the process of clinical care by increasing visit length and by improving clinic formularies and referral patterns the cost impact of converting one facility to IMCI extends beyond the one time cost of training, to include changes in the facility's unit cost of treating a sick child. Prior cost studies of IMCI have focused on the average incremental costs of IMCI at the district or regional level (Adam *et al.*, 2005b; Armstrong Schellenberg *et al.*, 2004a). Specifically in prior cost studies the average cost per child is computed in IMCI facilities in a health service area and then compared to average cost per child treated in facilities in a comparison area. A comparison of facility costs between clinics implementing IMCI and those implementing usual care in Tanzania was unable to demonstrate any difference in the average cost of care per child (Adam *et al.*, 2005b; Armstrong Schellenberg *et al.*, 2004a). There have been no studies of the marginal cost to treat one more child using IMCI compared to the marginal cost of treating one more child in standard practice.

The benefits of IMCI relate primarily to the structure and process of care, which should influence clinical outcomes like child survival. Training workers in IMCI has been consistently shown to improve the quality of care (Adam *et al.*, 2005a; Amaral *et al.*, 2005; Arifeen *et al.*, 2005; Armstrong Schellenberg *et al.*, 2004a, b; El Arifeen *et al.*, 2004; Gouws *et al.*, 2004; Pariyo *et al.*, 2005; Rowe *et al.*, 2000). However, successfully measuring how higher quality affects health outcomes and attributing outcome changes to a marginal decision to convert a dispensary to IMCI has proven difficult. One prospective trial found steeper declines in child mortality in two Tanzanian districts that implemented IMCI in 2000 compared to the two scheduled for later implementation (Armstrong Schellenberg *et al.*, 2004b). In Peru, in 2000, no impact of IMCI on mortality could be identified (Huicho *et al.*, 2005); however, IMCI implementation did not include adequate health system support, and child mortality levels were already quite low in Peru (Victora *et al.*, 2005). One interpretation of the evidence is that IMCI definitely improves health service quality, but depending on the context may or may not also improve child survival (Victora *et al.*, 2005).

Having a technique to improve health service quality constitutes progress because of the growing recognition that quality improvement is an independent goal of health policy. The United Nations has declared the provision of high-quality health facilities to be an essential element that must be addressed to guarantee citizens the right to health (United Nations Committee on Economic Social and Cultural Rights, 2000). In the rights-based framework of the UN, states should improve health service quality to guarantee the rights of their citizens, not to the extent that quality improvement is efficient, nor to the extent that quality saves lives. We explicitly disagree with frameworks that only see value in improving the quality of provider behavior when it is possible to directly link quality measures to patient outcomes (Mason *et al.*, 2001). The types of quality measures that lend themselves to this sort of outcome-based analysis will tend to be discrete and unidimensional (e.g. provider prescribed X), whereas the type of provider quality that many decision-makers seek to achieve is more global and multidimensional.

Given a commitment to improve health service quality as a policy goal unto itself, a policymaker would certainly wish to consider an approach like training workers in IMCI. Yet a policymaker would wish to know how scaling up IMCI training might impact health-care costs because of the longer visits

and improved use of drugs. The appropriate margin for economic analysis is not the central decision to adopt IMCI, but the marginal decision to convert one more facility to the use of the IMCI guidelines. Health planners in over 100 countries around the world have already ‘adopted’ IMCI as a national goal that will take time to fully implement (World Health Organization, 2005). Subsequent to these IMCI adoption decisions, millions of dollars will be spent in coming years continuing to scale up IMCI throughout the world. The decision-makers who invest in the scale-up decisions will want to know what they are achieving in return for the investment. They will plausibly expect an improvement in service quality at each clinic that is enfolded into IMCI, and they will expect that the better quality may alter each clinic’s costs. Yet the precise relationship between improved clinical quality achieved by implementing IMCI and facility level costs is unknown. On the one hand, IMCI could lower costs by making drug prescriptions more judicious or by preventing illnesses by improved vaccination and parental counseling. IMCI could also raise costs by increasing visit length.

Prior studies of IMCI have not explored the correlation between measures of service quality and the costs of delivering care to small children. There have been no prior studies of the marginal cost impact of treating one more child in primary care using IMCI-based strategies. There have been no studies to date that could inform planners about the relationship between facility quality and facility costs. The goal of this paper is to use data from Uganda to measure the marginal change in costs of medical care for children under five from a unit increase in quality of care achieved through the IMCI strategy at the facility level. Our econometric cost functions are based on the neo-classical theory of the firm and assume that each primary care facility is trying to ‘produce’ high-quality pediatric visits by selecting an efficient combination of inputs (staff time, drugs, buildings, equipment). This approach assumes that each facility faces input prices that are exogenous, that each has some scope of choice in how to produce patient visits, and that each is trying to be efficient. Although many associate the use of cost functions with studies of hospitals, the efficiency of health-care organizations in general lends itself to this approach. Cost functions have been applied to assess the efficiency of nursing homes and medical group practices (Jones, 2000).

This approach is not to be confused with a standard societal or medical sector cost-effectiveness analysis directed at estimating cost per disability adjusted life year (DALY) averted. Our analysis presumes that the policy goal is to improve health service quality for its own sake because quality health care is a UN sanctioned human right. The economic questions that we answer will help planners understand the cost consequences to their outpatient facilities of policies to improve health service quality. Thus, the analysis is done from the perspective of those who invest in IMCI training at primary care facilities. We model the cost consequences of IMCI training at the level of the individual primary care facility, because that is where IMCI changes practice most. The decision point is whether to scale up IMCI to one more facility and many of the cost consequences of IMCI occur at the facility level through changes in prescribing and staffing. IMCI training focuses on changing practices in outpatient care and that is where our cost model focuses. The drawback of focusing on outpatient costs is that our analysis will have limited value to decision-makers who wish to know the impact of higher-quality outpatient care on hospital costs due to altered referral patterns. Although IMCI is plausibly related to referral patterns, no studies of IMCI have yet measured how much IMCI affects the caseload at the hospitals in districts where IMCI is being phased in.

METHODS

Data

In 1995, the Ugandan Ministry of Health adopted a policy of training health workers in IMCI (Nsungwa-Sabiiti *et al.*, 2004). The data used for this study come from health facility surveys conducted as part of the Uganda IMCI Impact Study, which received ethical approval from the Uganda National

Council for Science and Technology and the Johns Hopkins School of Public Health Committee on Human Research. This study, which was conducted in 10 districts of Uganda, sampled health facilities from a universe of a total of 420 first-level facilities among which 288 were government facilities and 132 were NGO facilities. Initial random samples of eight first-level facilities were drawn from each of the 10 districts in 2000, stratified by the type of facility (dispensary, dispensary with maternity services, and health center). Both government and non-government health facilities were included, but outpatient clinics in hospitals were excluded. If a facility in the original sample was closed, the study team replaced it with one of two extra facilities included in the original sample for this purpose (Pariyo *et al.*, 2005).

Data on the quality of case management, based on direct observations of case management according to a protocol described as 'The Index of Integrated Child Assessment,' were collected from 78 first-level health facilities between July and December 2000 (Lambrechts *et al.*, 2001). The intended sample of 80 facilities could not be obtained since two of the originally selected facilities were closed and the two facilities selected in the replacement process were military or police clinics. The Index of Integrated Child Assessment, was developed by an interagency working group on IMCI monitoring and evaluation that was established in 1997 by WHO specifically to define a set of standard quality of care indices that could be used to evaluate the outcomes of IMCI training, worldwide (Gouws *et al.*, 2005). This index is a measure of health worker adherence to 14 essential tasks for assessment of the sick child, according to IMCI guidelines, and measures the quality and completeness of assessment received by a sick child presenting at the health facility. Details on the contents and validity of the index are provided elsewhere (Gouws *et al.*, 2005; Pariyo *et al.*, 2005).

Cost data were also collected from the same 78 first-level health facilities through a health facility cost survey administered between January and September 2001, covering data from the 1999–2000 fiscal year (July 1, 1999–June 30, 2000). The facility cost survey was developed jointly with personnel from the MultiCountry Evaluation of IMCI and is described in detail elsewhere (Adam *et al.*, 2004). Total cost of care for children under five was calculated for each facility by summing the proportion of indirect facility costs (labor, rent, equipment, utilities, fuel, and other operating costs) attributable to under-five care with the proportion of total drug costs for under-fives and total laboratory costs for children under five (Gold *et al.*, 1996).

In order to properly apportion overhead costs between the clinical care of children vs adults we undertook a small time and motion study in five of the original 10 study districts (Kumi, Masindi, Mubende, Iganga, and Bugiri). One health worker in each of the 34 facilities was observed for a total of 325 encounters with children under five, lasting a mean of 7.14 min and a median of 5 min and 355 encounters with those over the age of five, lasting a mean of 7.38 min and a median of 5 min. Since there was no statistically significant difference in mean and median visit durations, the proportion of indirect costs attributable to under-five care was calculated based on the proportion of total annual outpatient visits that were made by children under five. Proportion of drug costs for children under five was calculated based on the proportion of total prescriptions to children under five.

The original study design was intended to have been a longitudinal comparison of costs and outcomes as IMCI was initiated in a set of districts judged likely to implement IMCI early and matched comparison districts judged likely to implement after a delay of several years. Although the Ministry of Health adopted IMCI as a national policy in 1995, the decentralized nature of health services in Uganda permitted districts to choose whether or not to implement IMCI. To the detriment of the original study design, three of the four originally designated comparison districts (Bugiri, Iganga, Mubende) were already implementing IMCI at the time of the baseline health facility survey. Only one of the original comparison districts (Nebbi) had not begun implementation of IMCI by the time of the initial health facility survey. As shown in Table I, some of the originally designated comparison districts (Iganga and Mubende) achieved higher levels of IMCI implementation than some of the originally designated intervention districts.

Thus, the analysis originally planned became untenable because the intention to treat variable marking a facility as 'intervention' or 'comparison' had become meaningless. Another option that was considered was to make a distinction between 'IMCI-trained' and 'non-IMCI-trained' health facilities.

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Table I. IMCI status, by district

	District	Average percent of health workers trained in IMCI, per facility (a)	Average percent of children managed by a health worker trained in IMCI, per facility (b)	Percent facilities with any IMCI as of 2000 (a or b)	Number of health facilities surveyed
Intention to treat: intervention districts	Kiboga	55.2	62.5	75	8
	Kumi	11.8	24.7	50	8
	Luwero	21.5	68.1	75	8
	Masaka	33.2	72.9	100	8
	Masindi	35.4	30.5	75	8
	Ntungamo	12.1	65.3	75	8
Intention to treat: comparison districts	Bugiri	6.5	2.4	28.6	7
	Iganga	27.7	50	62.5	8
	Mubende	22.0	45.2	85.7	7
	Nebbi	0	0	0	8
	Total intervention	28.2	53.7	75	48
	Total comparison	14.1	22.6	43.3	30
	Total	22.8	41.2	62.8	78

However, we found that there were differing intensities of IMCI-training. In facilities where IMCI-training did in fact occur, not all of the health workers who case manage children were trained. Table II provides background information on both facilities that had any health workers trained in IMCI and facilities that had no health workers trained in IMCI.

‘Dose of IMCI’ as the independent variable

Because events in the field conspired against categorically defining facilities as ‘IMCI’ vs ‘non IMCI,’ a two group comparison of the mean cost per child would not be a valid measure of the average incremental cost of IMCI. Instead, we chose to measure the intensity, or ‘dose’ of IMCI-related service quality received by children at each facility.¹ Fortunately we have a very useful measure of the dose of IMCI in the form of a direct measure of service quality – the Index of Integrated Child Assessment, measured at each facility.

Because health worker adherence to training guidelines has been shown to decrease over time as shown by Pariyo and others, measures of adherence to guidelines rather than the percent of facility staff trained in IMCI can serve as a better indicator of the ‘dose’ of service quality received (Pariyo *et al.*, 2005). In addition, structural measures of quality such as percent of staff trained will be endogenously confounded with unobservable features of the facility that influenced the decision to undertake IMCI-training and which could be correlated with facility costs.

Advantages of process measures

The index of integrated child assessment has been validated by WHO for measuring health worker performance and the degree of compliance with IMCI guidelines in carrying out specific assessment

¹ In conceptualizing the dose of IMCI, we also considered two other variables: (1) proportion of health workers trained in IMCI at a facility; and (2) proportion of children who were treated by IMCI trained health workers at a facility. Each of these measures has serious limitations. The *proportion of health workers* (managing children) who are trained in IMCI is heavily skewed with 43% of facilities having a proportion of 0 and the remainder scattered nearly uniformly from 10 to 100% trained in IMCI. Proportion of children who were treated by IMCI trained health workers at a facility actually represents the *proportion of children* presenting for care on the day of the survey who are managed by a health worker trained in IMCI. This variable follows a bimodal distribution and conveys almost no information beyond whether a facility had trained any of its health workers in IMCI.

Table II. Descriptive data on sample

Dependent variable	IMCI facilities ^a		Non-IMCI facilities		All		χ^2/t -test <i>p</i> -value
	Obs	Mean or % (S.D.)	Obs	Mean or % (S.D.)	Obs	Mean or % (S.D.)	
Under-five cost ^b	49	\$6896.97 (\$4974.83)	28	\$4072.66 (\$2914.86)	77	\$5869.95 (\$4529.85)	0.01
Median (IQR) ^c	49	\$5709.77 (\$2847.03–\$9183.76)	28	\$3070.32 (\$1817.13–\$5945.19)	77	\$4963.86 (\$2191.56–\$8116.01)	0.04
<i>Independent variables</i>							
Facility type	49		28		77		0.00
Dispensary (level 2)		22.45		53.57		33.77	
Maternity unit (level 3)		38.78		39.29		38.96	
Health centre (level 4)		38.78		7.14		27.27	
Facility ownership	49		28		77		0.09
Public		89.80		75.00		84.42	
NGO		10.20		25.00		15.58	
District	49		28		77		0.00
Luwero		12.24		7.14		10.39	
Kumi		8.16		14.29		10.39	
Masindi		12.24		7.14		10.39	
Mubende		12.24		3.57		9.09	
Kiboga		12.24		7.14		10.39	
Masaka		14.29		0.00		9.09	
Ntungamo		12.24		7.14		10.39	
Nebbi		0.00		28.57		10.39	
Iganga		10.20		10.71		10.39	
Bugiri		6.12		14.29		9.09	
Intent to treat	49		28		77		0.01
Comparison		28.57		57.14		38.96	
Intervention		71.43		42.86		61.04	
Total facility utilization	49	13811.38 (10083.38)	28	13724.80 (10687.98)	77	13779.90 (10237.19)	0.97
Under-five utilization	49	7506.88 (5422.64)	28	8242.23 (6358.09)	77	7774.28 (5749.78)	0.59
Quality index of child assessment	48	52.57 (18.94)	28	36.62 (15.12)	76	46.69 (19.16)	0.00
Input prices							
Hourly wage rate	49	\$0.41 (\$0.16)	28	\$0.35 (\$0.17)	77	\$0.39 (\$0.17)	0.13
Rental price/ square meter	49	\$0.77 (\$0.96)	28	\$0.67 (\$0.45)	77	\$0.73 (\$0.81)	0.59

^aHaving at least one worker trained in IMCI.

^bAnnual facility costs of delivering care to children under 5 (Ush).

^cIQR = interquartile range.

Note: \$1.00 = 1700 Ush in 2001.

tasks and has also been proven to have a high degree of reliability with a Cronbach alpha coefficient of at least 0.80 (Pariyo *et al.*, 2005). The 14 items in this index are detailed elsewhere and provide a direct measure of the quality of both IMCI-training and the extent of health worker practice of IMCI (Gouws *et al.*, 2005; Pariyo *et al.*, 2005).

Conceptual model linking costs to dose of IMCI

Prior applications of the theory of the firm to health-care service production have distinguished quality and volume as separate outputs that will enter the cost function. Health-care providers produce both a volume (V) of services and an average per service quality (Q). To produce these outputs they purchase

inputs, such as personnel, capital, drugs, as well as in-service training to maintain or improve quality (Gold *et al.*, 1996).

The relationship between quality output and facility inputs can be operationalized with a production function for quality as follows:

$$Q_i = Q(\text{IMCI training, Drugs, Personnel} \mid \text{Volume of Patients}) \quad (1)$$

where Q_i is the quality of services produced by health facility 'i.' Q_i is a function of inputs such as the IMCI health worker training intervention, drugs, and personnel, conditional on the volume of services. The term 'volume' will be used interchangeably with utilization to represent total number of visits of children under five at the health facility. The two outputs of quality and volume are correlated with each other. Anticipating the cost implications, we note that IMCI training as an input will act as a technology shifter. After obtaining IMCI training, the facility may engage in a variety of new practices that change the cost of care. So although the cost of hiring one more worker is typically the wage of the worker multiplied by the hours contracted, the cost implications of obtaining IMCI training may be more complex.

To operationalize (1) for estimation we apply a linear functional form as follows:

$$\log Q_i = \beta_0 + \beta_1 I_i + \beta_2 F_{1i} + \beta_3 F_{2i} + \beta_4 \log V_i + \varepsilon_i \quad (2)$$

where Q_i , the quality of care for the '*i*'th facility, is measured as the mean facility score for the composite index of child assessment (Gouws *et al.*, 2005) and I_i is a dichotomous indicator of whether at least one health worker at facility '*i*' has received IMCI training. The coefficient β_1 represents the mean difference in quality scores between facilities that have at least one IMCI-trained health worker and facilities that do not have any health workers trained in IMCI. F_{1i} and F_{2i} are dummy variables representing whether facility '*i*' is a level 3 or level 4 health facility. The coefficients, β_2 and β_3 , each represent the mean difference in quality scores between each of the respective types of facilities and a level 2 facility. V_i represents volume of services provided at facility '*i*' and is included because the two outputs of quality and utilization are correlated with each other. A natural logarithmic transformation was applied to all continuous variables in the production function so that results could be interpreted in a common metric of elasticity, representing the percentage change in quality above the sample mean that would result from a facility's decision to train at least one health worker in IMCI.

Cost theory and empirical strategy

The cost of a firm's operation is dual to its profit function and is known to be a function of prices of the resources used in the production of the services (input prices) as well as the quantity of goods or services produced (outputs) (Varian, 1992). Applying such a production function to a facility producing both a volume of visits and quality of those visits yields a cost function as shown below

$$C_i = C(\text{Input Prices} \mid \text{Volume, Quality}) \quad (3)$$

To implement Equation (3) we linearize it as

$$\log C_i = \gamma_0 + \gamma_1 \log Q_i + \gamma_2 \log V_i + \gamma_3' P_i + \gamma_4' X_i + \varepsilon_i \quad (4)$$

where C_i , the outcome, is mean facility cost. Facility cost depends on two types of outputs, quality and volume, as well as input prices. Q_i represents the index of child assessment score at the '*i*'th health facility, V_i represents the total annual number of child health-care visits at facility '*i*', P_i is a vector of input prices and X_i is a vector of confounders such as level of facility and district dummy variables. A natural logarithmic transformation was applied to all continuous variables in the cost function so that results could be interpreted in a common metric of elasticity, representing the percentage change in costs above the sample mean that would result from a unit percentage increase in utilization (or quality) over baseline.

Regression analysis

When data from the cost survey and the quality survey were merged, there were 77 facilities in common. Therefore, this data set of 77 facilities forms the final data set used for analysis, out of which 49 facilities had at least one health worker trained in IMCI and 28 facilities had no health workers trained in IMCI. Descriptive data on the cost and quality indicators are shown in Table II. Missing data led to the omission of 1 observation – a rate of missingness less than 3%, which was considered negligible. All data analysis was done using the Stata statistical software package, versions 7 and 8. Equation (4) was estimated using ordinary least-squares regression. In a larger data set, we could have used the translog cost function, which is a flexible functional form that can accommodate nonlinearities such as increasing or decreasing returns to scale. The translog cost function incorporates second-order terms including squares of each independent variable and interactions between each independent variable. However, given the small size of our data set, there would be insufficient power to estimate these higher-order terms.

Post-regression analysis

Coefficient estimates from parameters (*A*) and (*B*) were multiplied to provide an estimate of parameter (*C*), the percent change in cost due to implementation of IMCI, as shown below

$$\begin{array}{rcccl}
 \text{Production function} & & \text{Cost function} & & \\
 \frac{\Delta \log \text{Quality}}{\Delta \text{IMCI}} & \times & \frac{\Delta \log \text{Costs}}{\Delta \log \text{Quality}} & = & \frac{\Delta \log \text{Costs}}{\Delta \text{IMCI}} \quad (5) \\
 (A) & \times & (B) & = & (C)
 \end{array}$$

Each of the two parameters (*A*) and (*B*) on the left-hand side of Equation (5) was obtained from separate regression estimates of the production function (regression coefficient for IMCI) and the cost function (regression coefficient for quality), respectively. The first parameter of the equation, (*A*), represents the effect of IMCI on quality, estimated as the regression coefficient for the IMCI variable (β_1) from Equation (2). The second component of the equation computes the elasticity of cost with respect to quality. The value of this second component, (*B*), is equal to (γ_1) from Equation (4) presented earlier. The new *suest* and *ncom* commands in Stata 8 were used to multiply the two coefficients and simultaneously derive a sandwich estimate of the standard errors of the product.

This approach to estimating $\Delta \text{Log Costs}/\Delta \text{IMCI}$ avoids the problems associated with directly regressing log costs on a dummy variable for IMCI. According to economic theory, an equation that regressed costs directly on IMCI would be misspecified, because IMCI, as one of the inputs into the production function (for sick child health facility visits and quality of these visits) would be directly correlated with the residuals in the health facility cost function. By structurally separating the estimate of the cost function and the estimate of the production function, the problems of misspecification are avoided. Furthermore, because IMCI training should alter costs only via a connection between training and the quality of facility practices, our two-step procedure parses out the effect of IMCI on costs attributable to better service quality. Endogeneity is not completely eliminated because clinics with an unobservable propensity towards higher quality may have endogenously selected IMCI training, biasing estimates of Equation (1). We examined available evidence to compare facilities that were IMCI adopters vs non-adopters to assess the potential magnitude of this bias as shown in Table III.

An alternative way to avoid a misspecification but to assess the impact of IMCI on costs more directly is to estimate the cost function Equation (4) in a stratified sample of IMCI vs non-IMCI facilities. If the coefficient on volume is larger in the IMCI facilities, it would indicate that the marginal cost per child seen is higher in IMCI facilities. This strategy is shown in Table VII.

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Table III. Associations of health facility background characteristics with decision to train health workers in IMCI

<i>Outcome: any health worker trained in IMCI</i>	Model 1	Model 2 ^a	Model 3 ^a
Dispensary (level 2)	Ref.	Ref.	Ref.
Maternity unit (level 3)	2.66 (1.60)	5.08** (3.89)	6.53** (5.43)
Health centre (level 4)	16.44*** (14.91)	28.60*** (34.94)	66.17*** (105.60)
Intervention district	5.11*** (3.01)	1.61 (2.78)	1.69 (2.87)
NGO facility	0.37 (0.27)	0.08* (0.11)	0.07* (0.11)
< 5 volume			1 0
Observations	77	62	62
Pseudo- <i>R</i> ²	0.23	0.31	0.33

Odds ratios presented; standard errors in parentheses.

*Significant at 10%; ** significant at 5%; *** significant at 1%.

^aModels 2 and 3 are adjusted for district dummies. *F*-test for joint significant of district dummies is 0.60 and 0.61 in models 2 and 3, respectively.

Table IV. Median cost per child treated

Facility type	IMCI facility ^a (Obs)	Non-IMCI facility (Obs)	All (Obs)	<i>p</i> -value of continuity-corrected chi-square test
Dispensary (level 2)	\$1.04 (11)	\$0.50 (15)	\$0.78 (26)	0.11
Maternity unit (level 3)	\$0.78 (19)	\$0.67 (11)	\$0.72 (30)	0.45
Health centre (level 4)	\$0.98 (19)	\$0.59 (2)	\$0.96 (21)	0.50
All	\$0.57 (49)	\$0.96 (28)	\$0.78 (77)	0.04

^aHaving at least one health-worker trained in IMCI.

RESULTS

Cost function estimates

Table II shows that both mean and median costs are substantially higher for facilities with the IMCI training; however, IMCI-trained facilities were more likely to have higher-level facilities, which likely have higher costs, as shown in Table III. Table IV undertakes a simple comparison of median costs per child treated and indicates higher median costs per child at IMCI-facilities, regardless of facility-level; however, the small sample sizes within this table impede the precision of statistical comparisons. The data show the skewing typical of cost data with average per child costs at study facilities having at least one IMCI-trained worker of \$1.02 and median per child costs of \$0.55. At non-IMCI facilities cost per child had an average of \$1.07 and a median of \$0.96.

Effect of IMCI on quality (production function)

The production function for service quality was estimated with respect to the IMCI status and results are shown in Table V. This model shows that quality, as measured by the index of integrated child assessment is approximately 44% higher in facilities with at least one health worker trained in IMCI as compared to facilities with no health workers trained in IMCI, adjusting for facility utilization as well as ownership of

facility. Mean quality scores for all 77 facilities, as measured by this index of integrated child assessment, were normally distributed with a mean of 46 and a standard deviation of 20, on a scale of 0–100.

Effect of IMCI on cost (cost function)

Results from estimating a cost function (Equation (4)) with respect to the output of health facility cost are shown in Table VI. When adjusting for total annual volume as well as facility level, quality elasticity of cost is 0.36 ($p = 0.04$, adjusted $R^2 = 0.44$) as shown in column D. As shown in Table VI column D, volume elasticity of cost is 0.44 ($p = 0.00$, adjusted $R^2 = 0.44$) when adjusting for level of facility and quality of child assessment. The stratified analysis by facility IMCI status (Table VII) shows marginal

Table V. Health facility production function for service quality

<i>Production function</i>	
IMCI facility ^a	0.44 ^{***} (0.10)
NGO facility ^b	0.34 ^{**} (0.14)
Log (volume of under-five visits) ^c	0.08 (0.05)
Constant	2.68 ^{***} (0.48)
Observations	76
Adjusted <i>R</i> -squared	0.2

Regression coefficients presented. Standard errors in parentheses.

^aHaving at least one health worker trained in IMCI.

^bFacilities operated by non-governmental organizations; reference category is government facilities.

^cThe log of the annual number of health facility visits for children under five.

Table VI. Cost function (Equation (4)): OLS regression of log under-five cost on log of outputs and input prices

Model	A	B	C	D	E
Description of variables on right-hand side of cost function model	Quality	Volume	Quality and volume	Model C + facility level	Model D + input prices (labor & rent)
Quality index	0.59 ^{***} (0.21)		0.46 ^{***} (0.17)	0.36 ^{**} (0.17)	0.31 ^{**} (0.14)
Volume of <5 visits		0.57 ^{***} (0.09)	0.54 ^{***} (0.09)	0.44 ^{***} (0.09)	0.35 ^{***} (0.08)
Dispensary (level 2)				Ref.	Ref.
Maternity unit (level 3)				0.22 (0.19)	0.18 (0.16)
Health centre (level 4)				0.66 ^{***} (0.22)	0.59 ^{***} (0.18)
Wage rate (hourly)					0.68 ^{***} (0.12)
Rental price/square meter					−0.03 (0.08)
Constant	6.14 ^{***} (0.78)	3.43 ^{***} (0.81)	1.95 ^{***} (0.04)	2.95 ^{***} (0.96)	4.62 ^{***} 0
Observations	76	77	76	76	76
Adjusted <i>R</i> -squared	0.09	0.32	0.38	0.44	0.62

Standard errors in parentheses.

*Significant at 10%; **significant at 5%; ***significant at 1%.

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cost with respect to volume is much greater in IMCI facilities (elasticity ranging from 0.48 to 0.75) than in non-IMCI facilities (elasticity ranging from 0.19 to 0.36). Therefore, we included a term for the interaction between IMCI and utilization in one model, but this specification produced an insignificant interaction term (not shown).

Results from the preferred specification (Column E) (adjusted $R^2 = 0.62$) showed a quality elasticity of cost of 0.31 ($p = 0.04$) as shown in Table VI. As shown in Table VIII, adjusting for volume, facility level, and facility ownership, a decision to train facility staff in IMCI in this broad sample of Ugandan facilities is associated with an increase in log costs of 0.135 at the facility level. Since the coefficient in a regression of log costs on a dummy variable approximates the percentage change in costs attributable to the dummied condition, we infer that IMCI is associated with roughly 13.5% higher costs.

DISCUSSION

The final cost function (adjusted $R^2 = 0.62$) showed that total costs rise 3.1% for every 10% increase in the quality score ($p = 0.04$) as shown in Table VI. We also stratified by whether or not a facility had any workers trained in IMCI and saw that, although not statistically significant, the marginal cost of each additional sick-child visit is greater in facilities with any health workers trained in IMCI than in facilities

Table VII. Cost function, stratified by IMCI status

	IMCI					No IMCI				
Quality index	0.24		0.2	0.2	0.22	0.67*		0.5	0.49	0.41
	-0.3		-0.2	-0.2	-0.17	-0.33		-0.33	-0.32	-0.28
Volume of <5 visits		0.75***	0.75***	0.71***	0.48***		0.36**	0.30*	0.2	0.19
		-0.1	-0.1	-0.11	-0.1		-0.15	-0.15	-0.16	-0.14
Dispensary (level 2)				Ref.	Ref.				Ref.	Ref.
Maternity unit (level 3)				0.02	0.32				0.21	-0.06
				-0.23	-0.2				-0.31	-0.29
Health centre (level 4)				0.2	0.43**				1.14*	1.29**
				-0.25	-0.21				-0.62	-0.56
Wage rate (hourly)					0.76***					0.62***
					-0.15					-0.22
Rental price/square meter					-0.02					0.04
					-0.07					-0.22
Constant	7.63***	2.06**	1.26	1.59	3.94***	5.64***	4.86***	3.66**	4.36***	5.63***
	-1.16	-0.88	-1.11	-1.2	-1.09	-1.17	-1.31	-1.5	-1.51	-1.39
Observations	48	49	48	48	48	28	28	28	28	28
Adjusted R-squared	-0.01	0.53	0.57	0.56	0.71	0.1	0.15	0.19	0.24	0.42

Standard errors in parentheses.

*Significant at 10%; ** significant at 5%; *** significant at 1%.

Table VIII. Final results

	Parameter	Source	β Coefficient	Standard error	90% confidence interval
(1)	$\frac{\Delta \log \text{Quality}}{\Delta \text{IMCI}}$	Production function	0.44	0.10	0.27–0.62
(2)	$\frac{\Delta \log \text{Costs}}{\Delta \log \text{Quality}}$	Cost function	0.31	0.14	0.07–0.54
(3)	$\frac{\Delta \log \text{Costs}}{\Delta \text{IMCI}}$	Product term of (1) and (2)	0.135	0.07 (robust)	0.01–0.26

with no IMCI-trained health workers, as shown in Table VII. This finding could be due to the higher fixed costs in IMCI-trained clinics partially stemming from the requirement for clinics to actually stock a supply of drugs that were largely unavailable and underutilized prior to IMCI adoption. Sick-child visits could take longer with IMCI-trained health workers and this may also play some role.

Effect of IMCI on cost

We conclude that a decision to train at least one health facility staff member in IMCI in this broad sample of Ugandan facilities would correspond roughly to a 13.5% increase in costs at the facility level, with a confidence interval of 1–26%.

Study limitations

One major limitation of this study is the potential for selection bias. If facilities that were pre-disposed to have higher quality and/or higher costs selectively enrolled staff in IMCI training, then we would mistakenly attribute to IMCI, effects that stem from this pre-disposition. Our results should be interpreted with caution because of the following varieties of selection bias:

- (1) Non-random program placement bias – facilities implementing IMCI were not randomly selected.
- (2) Self-selection bias by facilities – within a facility, it was not possible to randomize the health workers who received training.
- (3) Self-selection bias by patients – with higher perceived quality, parents whose children had more severe conditions may have selected to attend IMCI-enabled clinics. This bias would artificially raise the cost per child at IMCI clinics. A competing bias is that IMCI protocols lead to the referral of the most severe patients to tertiary centers. Referral would lower the facility's cost relative to a clinic that expended resources to manage these sicker children without referring.

We checked for possible selection biases by comparing baseline characteristics of IMCI adopting facilities with characteristics of non-adopting facilities as shown in Table III. Multivariate logistic regression was used to calculate the adjusted odds of the presence of IMCI training in facilities. Overall these baseline characteristics did not have a large effect on the probability of adopting IMCI (*F*-test *p*-value of 0.17 in model 2 and 0.27 in model 3 for joint significance of all variables) with the exception of the level of facility as shown in Table III.

In estimating the cost functions, we included as covariates all observable variables that are correlated with IMCI. Although we believe that there are unobservable factors that also cause a selection bias, we believe that their impact on our estimates would be the same size or smaller than the insignificant impact of the observed variables because many of these unobservables may be correlated with the observed confounding variables. One important unobservable factor could be case mix. If IMCI training attracts sicker patients to the clinic, this would be one mechanism that would increase costs. From the perspective of the health system, case mix effects over-estimate the cost impact of IMCI. Assuming that the sicker patients are re-directing themselves from hospitals and other facilities to IMCI facilities, costs are simply being shifted around and not increased. From the perspective of the facility, the potential for IMCI to increase facility costs due to a higher acuity case mix would be a valid consideration in an individual facility's decision to improve quality.

Another limitation is that this study addresses only the recurrent costs at the facility level after IMCI has been implemented. The IMCI training process requires the district or central health ministry to invest in administration and conduct of training as sunk costs. We considered training costs to be negligible in comparison to any cost implications IMCI might have on the process of delivering care.

However, IMCI might have more substantial cost implications in the health system if it leads to increased numbers of children being referred to hospitals.

CONCLUSION

This is the first study to estimate the marginal cost elasticity with respect to both increased volume of child health visits and improvements in the quality of medical care for children in Uganda. We note that the cost elasticity with respect to volume at 0.35 is less than 1 suggesting that there are diminishing marginal costs of seeing more patients and increasing returns to scale. In other words, given the utilization of these clinics in 2000 (7774 child visits per facility), additional children could be seen and the cost for each successive child seen would be lower than the one before. We would attribute these returns to scale to the possibility that clinics were not being utilized at full capacity.

Our estimate that having at least one health worker trained in IMCI only increases first-level facility costs by 13.5%, suggests the potential to improve quality dramatically with only a small ramification on the costs of care. These results may apply to other developing countries where IMCI has been implemented, but are dependent upon each country's individual utilization patterns for child health services at public health facilities, which still constitute the majority of facilities where health workers have been trained in IMCI. Since our results are interpreted in a common metric of elasticity and not Ugandan Shillings (USh) or USD, comparison across different models and countries is possible.

It should not be surprising that quality comes at a cost. A large part of the rise in health-care spending in any country is due to adoption of more costly innovations in the process of care. Although some aspects of low quality care that IMCI is designed to ameliorate are costly and wasteful, such as irrational drug prescribing, IMCI visits could take longer, and require the facilities to actually stock a supply of drugs that are often unavailable and underutilized prior to IMCI adoption.

Note that the cost elasticity of quality (0.31) is less than 1, suggesting that there are increasing returns to scale in quality. These results suggest that given the quality scores of health workers in integrated child assessment in 2000 (normally distributed with a mean: 46.7, S.D.: 19.2, and range of 9–90, out of a scale of 100) there is much room to improve quality, with incremental improvements in quality having successively smaller impacts on cost.

We intended our analysis primarily as a demonstration of the usefulness of applying the econometric cost function to facility level data on service costs and outputs in a low-income country. Although this was not a 'cost-effectiveness analysis' of IMCI, we believe the results have relevance in assessing IMCI as a health technology. Conventional cost-effectiveness analysis is exclusively concerned with the cost of each death averted or the cost per disability adjusted life year (DALY) averted. Yet one of the main effects of IMCI is to improve service quality as an end in itself. IMCI evaluation conducted in Tanzania indicated that good technical quality can be related to health status outcomes such as morbidity and mortality. This analysis reveals the cost implications of quality improvement in the Ugandan setting.

Finally, our results can be used to shed light on the overall cost ramifications of the IMCI strategy. Prior studies have shown that the *average* cost per child treated at the facility level is similar in IMCI and comparison districts. A recent evaluation of IMCI in Tanzania showed that the average costs of IMCI at the facility level were \$1.39 per sick-child visit in IMCI facilities and \$1.61 in comparison facilities (Bryce *et al.*, 2005a). The corresponding average costs per sick-child visit at primary facilities in our study were \$1.02 at facilities with at least one IMCI worker trained and \$1.07 where no workers were trained in IMCI. The costing algorithm in the Tanzanian study and the Ugandan study were designed for comparability and used similar costing instruments and accounting methods (Adam *et al.*, 2004).

The contribution of our study has been to produce an estimate of the marginal effects on costs and service quality of a decision to have at least one IMCI-trained worker at a facility that originally had none. Simple comparisons of average costs in our data as in prior studies show no significant differences

in average costs at the facility level due to IMCI. However, a marginal analysis that ties IMCI training to quality and quality to costs shows that on the margin, investing in IMCI training at a primary facility level can yield a significant 44.3% improvement in service quality for a modest 13.5% increase in annual facility costs.

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The authors declare no financial conflicts of interest.

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