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ABSTRACT

Background: The geographic distribution of health care funding in Canada has traditionally been based on past allocations and the distribution of health care facilities and providers. Whether this approach has succeeded in distributing resources among populations in keeping with relative health care needs is unknown.

Methods: Using data on self-assessed health status and utilization of health care services from the Ontario Health Survey, data on health care expenditures from the Ontario Ministry of Health and Long-Term Care, and population data from Statistics Canada, we compared actual health care expenditures for geographically-defined populations in Ontario to allocations based on relative population need as represented by age, sex and self-assessed health status. Comparisons were made at the regional (Health Region), district (District Health Council) and local (Public Health Unit) levels.

Results: Expenditures and needs-based allocations were significantly different for 4 of 7 regions, 9 of 15 districts and 23 of 42 local areas. At the regional level, needs-based allocations ranged from 8.9% higher to 6.4% lower than actual expenditures. For districts, needs-based allocations ranged from 12.9% higher to 9.8% lower than expenditures. At the local level, needs-based allocations ranged from 23.8% higher to 18.8% lower than expenditures. Intra-class correlation coefficients measuring agreement between needs-based per capita expenditures and actual per capita expenditures were 0.86, 0.74 and 0.58 for regions, districts and local areas respectively.

Interpretation: Although, on average, the differences between needs-based allocations and actual health care expenditures were not large, the discrepancies were substantial for many

geographic areas. The adoption in Ontario of funding methods based on relative population needs would improve equity in the allocation of health care resources to populations and result in a considerable redistribution of resources.

Keywords: Health care funding, health care resource allocation, Ontario, Needs-based funding, Equity.

INTRODUCTION

A basic objective of most publicly financed health care systems is to allocate health care resources among populations according to need.(1) This objective is consistent with the philosophy underlying the Canada Health Act.(2,3,4,5)

Traditionally, the geographic distribution of health care funding in Canada has been based on past allocations and the distribution of health care facilities and providers.(6,7,8,9,10,11,12) However, governments in Canada are increasingly considering or adopting approaches to health care resource allocation based on relative population needs.(6,7,8,9,10,11,12,13,14)

What is not known is whether the traditional approach to health care resource allocation has succeeded in distributing resources among populations in keeping with relative needs, despite not being explicitly needs-based. In this paper, we address this question by comparing actual health care expenditures for regional, district and local area populations in Ontario to allocations based on relative population need as represented defined by age, sex and self-assessed health.

The needs-based approach is *relative* in that total health care resources are distributed among geographically defined populations based on their level of need. The extent to which either the needs-based approach or the traditional approach can meet the absolute level of need depends, among other things, on the size of the budget. For brevity, in the remainder of this paper we use “need” to refer to relative population need for health care.

METHODS

Relative Needs-Based Allocations

In computing relative needs-based allocations, our measure of need was population size adjusted for the distribution of age, sex and self-assessed health status in the population. Variation in age and sex distributions among populations captures a substantial portion of variation in illness-related need for health care because, at the population level, the risk of experiencing health problems varies substantially and predictably with age and

sex.(15,16,17,18,19) Age and sex also capture much of the variation in need for preventive and reproductive care.(20)

We used self-assessed health status to represent the variation in need that is not accounted for by age and sex. An impressive body of evidence supports the validity of self-assessed health status as a health status measure. Numerous studies have demonstrated statistically significant relationships, usually of moderate strength, between variants of this single item measure of self-assessed health and other measures of health status, including physician assessments (21,22,23,24,25), measures of functional ability/disability (24,26,27,28), number and/or type of self-reported health problems, diagnoses or chronic diseases (24,26,28,29), number of medications (24,29), acute symptoms (28), and composite measures of health status based on either self-reports (30) or a combination of physician- and self-reported conditions and health service utilization data.(31)

Idler and Benyamini reviewed 27 longitudinal studies and found that self-assessed health status was nearly always an independent predictor of mortality.(32) Adjustment for other health status measures sometimes diminished but rarely eliminated the significant independent effect of self-assessed health.

For this study, we obtained data on self-assessed health status and self-reported utilization of health care services from the 1990 Ontario Health Survey (OHS) and data on health care expenditures from the Ontario Ministry of Health. At the time the data for this study were assembled and analyzed, the most recent available health survey data were from the 1990 OHS and the most recent available health care expenditure data were from fiscal year 1995-96. Our analysis assumes – reasonably, we think – that between 1990 and 1995-96 major changes in the geographic distribution of health status within age categories were unlikely.

Self-assessed health status was asked of all OHS respondents 12 years of age and over as part of the self-complete portion of the survey (response rate 77.2%). For children less than 12 years of age we used proxy respondent reports from the personal interview component of the

OHS (response rate 87.5%) on the presence or absence of activity-limiting health problems. Complete information for age, sex and health status was available for 62,413 respondents (98.8% of those who responded to both components of the survey).

To use the population distribution of age, sex and health status to allocate resources, we estimated the relationship between these variables and relative need for health care resources as represented by existing utilization and expenditures at the provincial level. We assumed that, *at the provincial level of aggregation*, the population in each age/sex/health status category received an appropriate *relative share* of health care resources. It is important to note that our approach did not assume that existing allocations to age/sex/health status categories within and among regional, district and local populations are necessarily appropriate.

For this study, we considered only those categories of health care resources that were examined in the OHS. For health professional services, the interview portion of the OHS contained self-reported information on the number of contacts with general practitioners, specialist physicians, optometrists, physiotherapists and chiropractors during the preceding twelve months. The health professionals for whom data were available from the OHS accounted for 97% of all Ontario Health Insurance Plan (OHIP) dollar expenditures. For hospital services, the OHS provided the self-reported total number of nights spent in hospital during the preceding twelve months. Acute hospital costs account for 66% of the overall operation of hospitals. Table 1 shows that together these categories represent 56% of the 1995-96 Ministry of Health expenditures for the provision of health care services.⁽³³⁾ Hence, we are able to compare health care expenditures to needs-based allocations for services that make up over one-half of the total Ministry budget.

Geographic Units

The OHS was designed “to provide accurate and meaningful information at the Public Health Unit (PHU) level for all major indicators and characteristics.”⁽³⁴⁾ PHUs in Ontario typically represent regional municipalities or counties. The 1995 population estimates for PHUs

range from 39,832 for Timiskaming to 875,588 for Peel. Local areas for this study were defined by PHUs. The local areas can be aggregated into larger administrative areas called health districts which ranged in population from 222,808 for the health district of Muskoka, Nippissing, Parry Sound and Timiskaming to 2,420,054 for Metropolitan Toronto (smaller districts were amalgamated in 1998 to those used in this study). Districts can in turn be aggregated into health planning regions (reorganized in 1999 to those used in this study) which are the largest administrative area with 1995 populations ranging from 919,310 for North to 2,420,054 for Toronto.

Health Care Expenditures

A critical requirement was that the health care expenditures for regions, districts and local areas be computed on the basis of the place of residence of the recipients of services, rather than on the basis of the location of health care providers and institutions. From the Ontario Ministry of Health, we were able to obtain acute hospital expenditures and fee-for-service payments for physician and practitioner services based on the residence of the recipients. These expenditures represented most of the budget considered in this study (97%). However, alternate payments for physician services, also obtained from the Ontario Ministry of Health, were based on the location of the provider and represented 3% of the budget considered in this study. For the hospital data, place of residence was based on the patient address as indicated by the patient on the hospitalization record. However, in the health professional (OHIP) data the patient address originates from the Health Card which was introduced in 1991/92. During the period when the OHIP data used in this study were collected, there were no systematic mechanisms in place for updating health card addresses, so some patient addresses may have been out of date. The degree of error in patient addresses probably varies by geographic area and would have the largest impact on this study at the smallest geographic level, the local area. The effect of any out of date addresses would be smaller at the district and regional levels.

Estimating Needs-Based Allocations

Age, sex and health status-specific resource shares were computed for each type of health professional service and for acute hospital services in two steps. First, the age- sex-specific resource shares were calculated based on the distribution of Ministry of Health expenditures for the fiscal year 1995-96 *between* age/sex strata. To illustrate, males aged 40-44 years represented 4% of the population but accounted for 3% of the provincial expenditures on general/family practitioner services. The provincial per-capita expenditure on general/family practitioner services was assigned a value of 1, so the per-capita resource share for males aged 40-44 was $0.03/0.04=0.75$.

The second step was to calculate resource shares across health status levels *within* age/sex strata by determining the proportion of the particular health care service used during the preceding 12 months by persons in each of the five levels of self-assessed health from the OHS. For example, 7% of 40 - 44 year old males reported fair health but accounted for 13% of all self-reported general/family practitioner contacts in this age-sex group, so the needs-specific resource share for males aged 40-44 in fair health was $0.13/0.07 = 1.9$. Combining this with the previously computed resource share for 40-44 year old males (0.75), resulted in an age/sex/health status specific share of provincial expenditures for general/family practitioner services of 1.4 (1.9×0.75) for males age 40-44 years in fair health. That is, the needs-based share of resources for general/family practitioner services for a 40-44 year old male in fair (self-assessed) health would be 1.4 times the provincial per-capita expenditure on general/family practitioner services. The formula for the general/family practitioner need-specific shares is:

$$NSS_{i,j,h} = \left[\frac{\text{proportion of provincial expenditures accounted for by cell } i, j}{\text{proportion of provincial population accounted for by cell } i, j} \right] \times \left[\frac{\text{proportion of physician contacts within cell } i, j \text{ for individuals within cell } i, j, \text{ with health status } h}{\text{proportion of population within cell } i, j, \text{ within health status } h} \right]$$

for i =sex, j =age group, and h =health status.

Resource shares for each type of service were weighted according to the proportion of the total 1995-96 health care budget allocated to that service and then summed in order to compute overall needs-specific resource shares for each age/sex/health status category.

Population data by age and sex at the census division level were obtained from Statistics Canada CANSIM estimates for July 1, 1995. These data were aggregated and combined with the OHS data by local areas, districts and regions to obtain estimates of age, sex and health status distributions of the populations in these geographic areas. The needs-adjusted dollar allocations for each geographic area were calculated by multiplying age, sex- and health status-specific population estimates for the area by the corresponding resource shares, summing for the area to get total shares, and multiplying by the provincial per-capita expenditure for the health care services included. Per-capita needs-based expenditures were calculated by dividing each area's total dollar allocation by its total population.

Comparing Expenditures with Needs-based Allocations

Standard errors and confidence intervals were calculated for the estimates of the needs-based allocations. Appendix 1 shows the derivation of the formula used. The power to detect relative differences of 5% and 10% between expenditures and needs-based allocations was also calculated. Intraclass correlation coefficients were used to measure agreement between needs-based and actual per-capita expenditures.(35)

RESULTS

Tables 2 to 4 compare expenditures and needs-based allocations for regions, districts and local levels, respectively. Expenditures and needs-based allocations were significantly different for 4 of the 7 regions (57%), 9 of the 16 districts (56%) and 23 of the 42 local areas (55%). We had at least 80% power to detect a 5% difference in 7 of the 7 regions (100%), 3 of the 16 districts (19%) and 4 of the 42 local areas (10%). We had at least 80% power to detect a 10%

difference in 7 of the 7 regions (100%), 14 of the 16 districts (88%) and 17 of the 42 local areas (40%).

At the regional level, needs-based allocations ranged from 8.9% higher than expenditures for Central West to 6.4% lower than expenditures for Toronto, with a mean absolute difference of 4.2% (Table 2). At finer geographic levels the relative difference between expenditures and needs-based allocations was greater. For districts, the needs-based allocations ranged from 12.9% higher than expenditures for Waterloo Region-Wellington-Dufferin to 9.8% lower than expenditures for Hamilton-Wentworth, with a mean absolute difference of 5.8% (Table 3). At the local level, needs-based allocations ranged from 23.8% higher for Northwestern to 18.8% lower for Kingston, Frontenac, Lennox and Addington, with a mean absolute difference of 8.0% (Table 4).

At the regional level, Toronto region had the highest average per-capita needs and the highest per-capita expenditures (Table 2). Central West had the lowest per-capita needs and the lowest expenditures.

At the district level, Muskoka-Nipissing-Parry Sound-Timiskaming's needs per-capita were the highest but Metro Toronto received the most per-capita (Table 3). Both needs and expenditures were lowest for Halton-Peel.

At the local level, York City (within Metropolitan Toronto) had the highest per-capita needs while Toronto City had the highest per capita expenditures (Table 4). York region (the local area north of Metropolitan Toronto) had the lowest per-capita needs and received the fewest resources per-capita.

Intraclass correlation coefficients measuring the agreement between needs-based per-capita expenditures and actual per-capita expenditures by place of residence were 0.86, 0.74 and 0.58 for regions, districts and local areas respectively. Figure 1 shows the needs-based allocations plotted against actual expenditures.

DISCUSSION

Our results suggest that health care expenditures are not fully consistent with relative population needs for health care. However, the high intraclass correlations at the regional and district levels between per-capita needs-based allocations and per-capita expenditures indicate that in many cases expenditures are quite closely aligned with need. Despite this, implementation of needs-based funding would see a substantial redistribution of resources, especially at the local level. The potential redistributions are proportionally larger for smaller geographic areas because large aggregations average out variability within a region or district. Future research might explore whether there are systematic differences in geographic area characteristics that are related to the probability of relative over- or under-funding.

This study is limited in its conclusions to the 56% of total expenditures by the Ontario Ministry of Health for the provision of health care services that we were able to include in our analysis. Also, we did not adjust the needs-based allocations for differential costs between regions beyond those caused by differences in need. Because there has been limited examination of unavoidable geographical variation in the cost of providing health care in Ontario, we had no data on which to base such an adjustment.

Alternate payments, which represent 3% of all expenditures allocated in this study, were based on the location of provider. For the primary care portion of alternate payments, the location of the provider is likely to be fairly close to the place of residence of the recipient of the services. As a result, primary care alternate payments for out-of-area residents would be small relative to payments for in-area residents. However, some providers who receive alternate payments serve broad areas, for example, physicians on the staff of the Hospital for Sick Children in Toronto and specialist physicians participating in the Southeastern Ontario Academic Medical Organization associated with Queen's University in Kingston. This would have the effect of over-estimating current expenditures for areas in which these organizations are located while under-estimating current expenditures for areas in which out-of-area patients

reside. For example, Kingston-based medical specialists received almost 44 million dollars in alternate payments in 1995-96. If 50% of the services of these specialists were provided to patients living outside the Kingston, Frontenac, Lennox and Addington Public Health Unit area, the difference between the per-capita needs-based allocation and per-capita expenditures for that PHU would decrease from \$182 to \$59 and the relative difference from 19% to 7%. Specialists located in the Toronto City Public Health Unit area, mainly those associated with the Hospital for Sick Children, received over \$47 million in alternate payments in 1995-96. If 70% of their services were provided to out-of-area residents, the per-capita difference between the needs-based allocation and actual expenditures for the Toronto City PHU would be reduced from \$140 to \$91, and the relative difference from 13% to 9%.

CONCLUSIONS

Although on average the difference between needs-based allocations and actual health care expenditures were not large, ranging from 4.2% at the health region level to 8.0% at the Public Health Unit level, for many geographic areas the discrepancies were substantial (up to 8.9% at the health region level, 12.9% at the district health council level and 23.8% at the public health unit level). Based on these findings, the adoption of new funding methods based on relative population needs would improve equity in the allocation of resources to populations and result in a considerable redistribution of resources. Replication of our analysis as new data become available would establish whether discrepancies between needs-based allocations and those resulting from traditional funding approaches are changing over time.

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Table 1: 1995-96 Ministry of Health expenditures* for the provision of health care services and expenditures included in this project

Details of Expenditure	Ministry of Health (dollars)	Project (dollars)	Percent Covered by project
Grants Subsidies, etc.			
Operation of Hospitals	7,248,400,712	4,764,397,791	65.7%
Operation of Related Facilities	330,273,850		0.0%
Ontario Health Insurance Plan (OHIP)	4,690,862,555	4,553,431,264	97.1%
<i>Fee-for-service to physicians/practitioners</i>	4,410,760,466	4,273,329,175	96.9%
<i>Alternate payments†</i>	123,597,234	123,597,234	100.0%
<i>Health Service Organizations†</i>	77,136,300	77,136,300	100.0%
<i>Community Health Centres†</i>	79,368,555	79,368,555	100.0%
Ontario Drug Benefit Plan	1,002,165,174		0.0%
Mental Health (Community and Institutional-Based)	143,089,554		0.0%
Official Local Health Agencies	185,301,294		0.0%
Ambulance and Related Emergency Services	176,898,464		0.0%
Long Term Care	2,200,262,325		0.0%
Other	767,520,519		0.0%
Government Pharmacy Account	4,659,329		0.0%
Total Expenditures*	16,749,433,776	9,317,829,055	55.6%

* These expenditures exclude those not directly used for the provision of health care services, such as, Ministry staff salaries, benefits and travel, Ministers' salaries, Parliamentary Assistants' salaries, Ministry materials and supplies, funding for district health councils, the Health Resources Development Plan and Professional Relations, the Association of Local Official Health Agencies, the Ontario Council on Community Health Accreditation, the Ontario Public Health Association, clinical education and research.

† Preliminary estimates from the Ministry of Health based on unpublished data.

Source: PUBLIC ACCOUNTS 1995-96, Volume III – Ministry of Health.(33)

Table 2: Needs-Based Allocations and Health Care Expenditures (1995-96) at the Health Region Level*

Region	Needs-Based Allocation	Expenditures	Difference between Needs-Based Allocation and Expenditures	
	Per-capita in dollars (95% CI)	Per-capita in dollars	Per-capita Difference in dollars†	Relative Difference (%)‡
South West (SW)	835 (812, 858)	843	-8	-1.0
Central South (CS)	872 (846, 897)	876	-4	-0.5
Central West (CW)	750 (733, 767)	689	61§	8.9§
Central East (CE)	779 (759, 799)	728	51§	7.0§
Toronto (TO)	898 (879, 917)	959	-61§	-6.4§
East (E)	799 (776, 822)	831	-32§	-3.9§
North (N)	895 (865, 925)	881	14	1.6
Total				
Total in thousands of dollars	829	829		
Mean absolute difference			33	4.2

* These allocations include general practitioner, all medical specialists, optometrists physiotherapists, chiropractors and acute hospital covering 56% of the total expenditures by the Ministry of Health for the provision of health care services in 1995-96.

† Needs-Based – Expenditures; calculations based on unrounded data.

‡ (Needs-Based – Expenditures)/Expenditures; calculations based on unrounded data.

§ Significantly different at the 5% significance level.

Table 3: Needs-Based Allocations and Health Care Expenditures (1995-96) at the Health District Level*

Region	District	Needs-Based Allocation	Expenditures	Difference between Needs-Based Allocation and Expenditures	
		Per-capita in dollars (95% CI)	Per-capita in dollars	Per-capita Difference in dollars†	Relative Difference (%)‡
SW	Essex-Kent-Lambton	848 (808, 888)	890	-42§	-4.7§
	Thames Valley	816 (782, 851)	788	28	3.6
	Grey-Bruce-Huron-Perth	844 (792, 895)	856	-12	-1.4
CS	Niagara	903 (858, 949)	819	84§	10.3§
	Hamilton/Wentworth	861 (824, 898)	954	-93§	-9.7§
	Grand River	838 (779, 897)	817	21	2.6
CW	Halton-Peel	728 (707, 748)	682	46§	6.7§
	Waterloo Region-Wellington-Dufferin	793 (760, 826)	702	91§	12.9§
CE	Durham-Haliburton-Kawartha-Pine Ridge	824 (790, 857)	781	43§	5.5§
	Simcoe-York	743 (717, 769)	685	58§	8.5§
TO	Metropolitan Toronto	898 (879, 917)	959	-61§	-6.4§
E	Champlain	786 (759, 813)	816	-30§	-3.7§
	Quinte-Kingston-Rideau	828 (783, 873)	865	-37	-4.3
N	Algoma-Cochrane-Manitoulin-Sudbury	891 (847, 936)	911	-20	-2.2
	Muskoka-Nipissing-Parry Sound-Timiskaming	954 (884, 1024)	895	59	6.6
	Northwestern	852 (797, 906)	818	33	4.0
	Total				
	Total in thousands of dollars	829	829		
	Mean absolute difference			47	5.8

* These allocations include general practitioner, all medical specialists, optometrists physiotherapists, chiropractors and acute hospital covering 56% of the total expenditures by the Ministry of Health for the provision of health care services in 1995-96.

† Needs-Based – Expenditures; calculations based on unrounded data.

‡ (Needs-Based – Expenditures)/Expenditures; calculations based on unrounded data.

§ Significantly different at the 5% significance level.

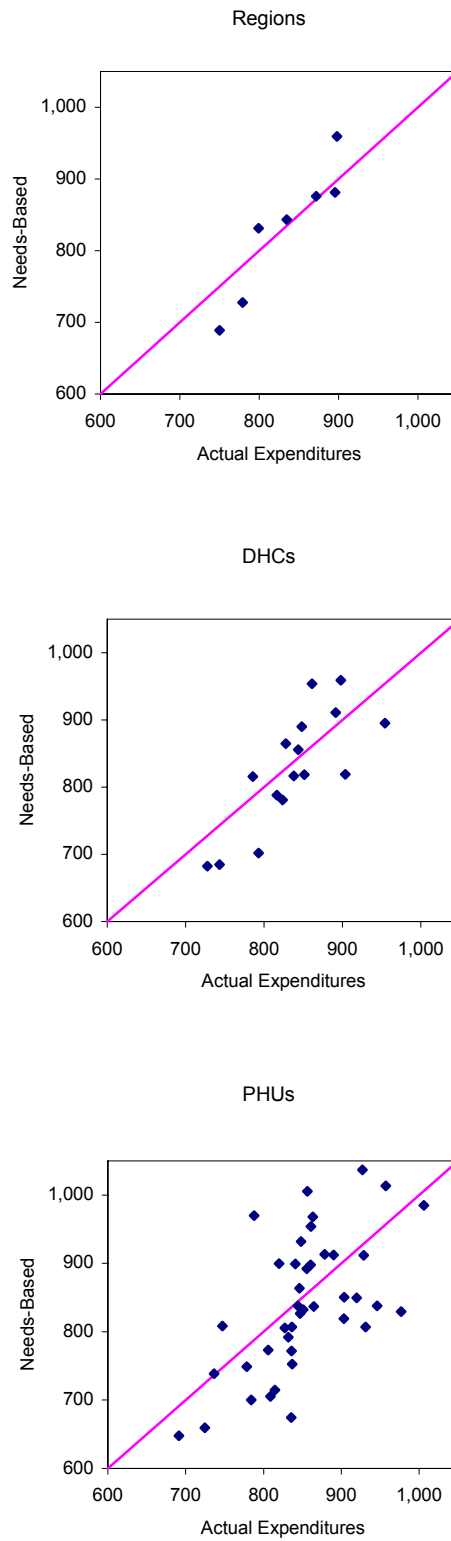
|| Peel is located in the region of Central East.

Table 4: Needs-Based Allocations and Health Care Expenditures (1995-96) at the Public Health Unit Level*

Region	Local Area	Needs-Based Allocation	Expenditures	Difference between Needs-Based Allocation and Expenditures	
		Per-capita in dollars (95% CI)	Per-capita in dollars	Per-capita Difference in dollars†	Relative Difference (%)‡
SW	Windsor-Essex	841 (795, 887)	899	-59\$	-6.5\$
	Kent-Chatham	904 (813, 995)	850	53	6.3
	Sarnia-Lambton	820 (750, 890)	900	-80\$	-8.9\$
	Middlesex-London	806 (771, 840)	773	33	4.2
	Elgin-St Thomas	844 (753, 935)	838	6	0.7
	Oxford	836 (754, 918)	807	29	3.6
	Bruce-Grey-Owen Sound	856 (786, 925)	892	-37	-4.1
	Huron	848 (752, 944)	932	-84	-9.0
	Perth	815 (734, 896)	715	100\$	14.0\$
CS	Niagara	903 (861, 946)	819	84\$	10.3\$
	Hamilton-Wentworth	861 (826, 896)	954	-93\$	-9.7\$
	Brant	847 (773, 920)	827	20	2.5
	Haldimand-Norfolk	827 (752, 903)	805	22	2.7
CW	Halton	736 (704, 769)	739	-2	-0.3
	Peel	724 (702, 747)	660	65\$	9.8\$
	Wellington-Dufferin-Guelph	809 (757, 861)	705	104\$	14.7\$
	Waterloo	784 (745, 824)	700	84\$	12.0\$
CE	Haliburton Kawartha	931 (862, 1001)	807	124\$	15.4\$
	Peterborough	846 (777, 915)	864	-18	-2.1
	Durham	778 (740, 817)	749	29	3.9
	York Region	691 (666, 717)	648	44\$	6.8\$
	Simcoe	837 (794, 880)	753	84\$	11.2\$
TO	East York	927 (845, 1009)	1037	-110\$	-10.6\$
	Etobicoke	890 (845, 935)	912	-22	-2.4
	North York	863 (832, 895)	968	-104\$	-10.8\$
	Scarborough	832 (799, 864)	792	40\$	5.0\$
	Toronto City	959 (922, 997)	1099	-140\$	-12.7\$
	York City	1006 (924, 1089)	985	21	2.1
E	Ottawa Carleton	747 (723, 771)	808	-61\$	-7.6\$
	Eastern Ontario	851 (793, 910)	832	19	2.3
	Renfrew	946 (851, 1041)	838	108\$	12.9\$
	Leeds, Grenville and Lanark	865 (790, 940)	837	28	3.3
	Hastings Prince Edward	836 (773, 898)	772	64\$	8.3\$
	Kingston, Frontenac, Lennox and Addington	788 (729, 847)	970	-182\$	-18.7\$
N	Algoma	857 (777, 936)	1006	-149\$	-14.8\$
	Sudbury	920 (861, 978)	850	70\$	8.3\$
	Porcupine	879 (787, 970)	913	-34	-3.8
	North Bay	929 (827, 1030)	912	17	1.9
	Timiskaming	957 (797, 1118)	1013	-56	-5.5
	Muskoka-Parry Sound	977 (878, 1075)	830	147\$	17.7\$
	Thunder Bay	860 (794, 927)	898	-38	-4.2
	Northwestern	836 (756, 915)	675	161\$	23.8\$
	Total				
	Total in thousands of dollars	829	829		
	Mean absolute difference			67	8.0

- * These allocations include general practitioner, all medical specialists, optometrists, physiotherapists, chiropractors and acute hospital covering 56% of the total expenditures by the Ministry of Health for the provision of health care services in 1995-96.
- † Needs-Based – Expenditures; calculations based on “unrounded” numbers.
- ‡ (Needs-Based – Expenditures)/Expenditures; calculations based on “unrounded” numbers.
- § Significantly different at the 5% significance level.
- || Data on alternate payments for physician services were not available for the local areas within Metro Toronto. We estimated the HSO portion of the alternate payments in each local area within Metro Toronto using the number of patients enrolled in HSOs and the average per-capita payment to HSOs. The remainder of the alternate payments were distributed through the local areas according to population.

Figure 1: Per-Capita Needs-Based Allocations versus Actual Expenditures*



*The diagonal line on each graph represents needs-based allocations = actual expenditures.

Appendix 1

Confidence Interval Derivation for Needs-Based Allocations

The variance of the needs-based allocation (NBA) for a given geographic region is

$$\begin{aligned} Var(NBA) &= Var(C1\hat{Y}) \\ &= C1^2 Var(\hat{Y}) \end{aligned} \quad (1)$$

where C1 is the provincial per capita expenditure in which sampling variability is disregarded and Y is the total resource shares for the geographic region. Now,

$$\hat{Y} = \sum_{i,j,k} NSS_{i,j,k} n_{i,j,k} \quad (2)$$

where $NSS_{i,j,k}$ is the need-specific share and $n_{i,j,k}$ is the estimated population of the given geographic region for age group i, sex j and health status group k.

$$NSS_{i,j,k} = \sum_t K_t NSS_{t,i,j,k}$$

where t indicates the type of service (general practitioner, specialist, optometry, physiotherapy, chiropractic or acute hospital) and K_t is the proportion of the Ministry of Health budget covered by each type of service. For each t,

$$NSS_{t,i,j,k} = C2_{t,i,j} \frac{p1_{t,i,j,k}}{p2_{i,j,k}}$$

where $C2_{t,i,j}$ is the ratio of the proportion of provincial expenditures for service t accounted for by age-sex group (i,j) to the proportion of the provincial population in that group. Because this ratio is based on provincial data from the Ontario Ministry of Health, sampling variability can be disregarded. The proportion of health care service contacts (or acute hospital nights stayed) for service t for age-sex group (i,j) that are associated with individuals in health status group k for the province is $p1_{t,i,j,k}$ and the proportion of the Ontario Health Survey (OHS) provincial sample in group (i,j) that are in health status group k is $p2_{i,j,k}$.

In (2), $n_{i,j,k}$ is estimated from Statistics Canada regional population figures by age and sex, $N_{i,j}$, combined with the proportion of the age-sex group in health status k for that geographic region estimated from the OHS, $rp2_{i,j,k}$, such that,

$$n_{i,j,k} = N_{i,j} rp2_{i,j,k}$$

Then, from (2)

$$\begin{aligned} Var(\hat{Y}) &= Var \left[\sum_{i,j,k} \left(\sum_t K_t C 2_{t,i,j} \frac{p1_{t,i,j,k}}{p2_{i,j,k}} \right) (N_{i,j} r p 2_{i,j,k}) \right] \\ &= \sum_{i,j,k,t} Var \left[K_t C 2_{t,i,j} \frac{p1_{t,i,j,k}}{p2_{i,j,k}} N_{i,j} r p 2_{i,j,k} \right] \end{aligned}$$

assuming that the number of shares in each sex, age, health status and type of service group are independent of one another. So,

$$Var(\hat{Y}) = \sum_{i,j,k,t} K_t^2 C 2_{r,i,j}^2 N_{i,j}^2 Var \left(\frac{p1_{t,i,j,k} r p 2_{i,j,k}}{p2_{i,j,k}} \right). \quad (3)$$

Suppressing the subscripts for clarity and using Taylor series approximations we have,

$$Var \left(\frac{p1 r p 2}{p2} \right) = \left(\frac{p1 r p 2}{p2} \right)^2 Var \left[\ln \left(\frac{p1 r p 2}{p2} \right) \right]. \quad (4)$$

$$\begin{aligned} Var \left[\ln \left(\frac{p1 r p 2}{p2} \right) \right] &= Var [\ln(p1) + \ln(r p 2) - \ln(p2)] \\ &= Var [\ln(p1)] + Var [\ln(r p 2)] + Var [\ln(p2)] - 2 Cov [\ln(r p 2), \ln(p2)] \\ &= \frac{Var(p1)}{p1^2} + \frac{Var(r p 2)}{r p 2^2} + \frac{Var(p2)}{p2^2} - \frac{2 Cov(r p 2, r 2)}{r p 2 p 2} \end{aligned} \quad (5)$$

noting that p1 is independent of p2 and rp2. The proportion p1 is estimated by r1/n1 where r1 is the number of health care service contacts for type-of-service-age-sex-health status group (t,i,j,k) and n1 is the total number of health care service contacts for type-of-service-age-sex group (t,i,j). Similarly, p2 is estimated for the province by r2/n2 and rp2 is estimated for the geographic region by r2/rn2.

Note that the OHS data were population weighted for each public health unit, age and sex group. The analytic weights are used so as not to under-estimate the variance by using an inflated population size. In addition, to compensate for the cluster design that was used in the OHS we will divide the analytic weight by the square root of the appropriate design effect (deff).(36) For variance calculation purposes the weights, w, are given by,

$$\begin{aligned} w_{i,j,PHU} &= \frac{N_{i,j,PHU}}{n2_{i,j,PHU}} \frac{\sum_{i,j,PHU} n_{i,j,PHU}}{\sum_{i,j,PHU} N_{i,j,PHU} \sqrt{deff}} \\ &= \frac{N_{i,j,PHU}}{n2_{i,j,PHU} \sqrt{deff}} \frac{62,413}{11,098,109} \end{aligned}$$

From the binomial we have,

$$\text{Var}(p1) = \frac{r1}{n1^3}(n1 - r1),$$

$$\text{Var}(rp2) = \frac{rr2}{rn2^3}(rn2 - rr2),$$

and,

$$\text{Var}(p2) = \frac{r2}{n2^3}(n2 - r2)$$

where $r1$, $n1$, $r2$, $n2$, $rr2$ and $rn2$ are weighted as discussed above. To calculate the covariance, let $or2=r2-rr2$ and $on2=n2-rn2$ where o indicates all the other geographic regions.

$$\begin{aligned} \text{Cov}(rp2, p2) &= \text{Cov}\left(\frac{rr2}{rn2}, \frac{rr2 + or2}{rn2 + on2}\right) \\ &= \frac{rr2(rr2 + or2)}{rn2(rn2 + on2)} \text{Cov}\left[\ln\left(\frac{rr2}{rn2}\right), \ln\left(\frac{rr2 + or2}{rn2 + on2}\right)\right]. \quad (6) \\ \text{Cov}\left[\ln\left(\frac{rr2}{rn2}\right), \ln\left(\frac{rr2 + or2}{rn2 + on2}\right)\right] &= \text{Cov}[\ln(rr2) - \ln(rn2), \ln(rr2 + or2) - \ln(rn2 + on2)] \\ &= \text{Cov}[\ln(rr2), \ln(rr2 + or2)] - \text{Cov}[\ln(rr2), \ln(rn2 + on2)] \\ &\quad - \text{Cov}[\ln(rn2), \ln(rr2 + or2)] + \text{Cov}[\ln(rn2), \ln(rn2 + on2)] \\ &= \frac{\text{Cov}(rr2, rr2) + \text{Cov}(rr2, or2)}{rr2(rr2 + or2)} - \frac{\text{Cov}(rr2, rn2) + \text{Cov}(rr2, on2)}{rr2(rn2 + on2)} \\ &\quad - \frac{\text{Cov}(rn2, rr2) + \text{Cov}(rn2, or2)}{rn2(rr2 + or2)} + \frac{\text{Cov}(rn2, rn2) + \text{Cov}(rn2, on2)}{rn2(rn2 + on2)} \\ &= \frac{\text{Var}(rr2)}{rr2(rr2 + or2)} \end{aligned}$$

because all terms but the first are 0 because we condition on the n 's and only consider variation in the r 's. Thus, from (6),

$$\begin{aligned} \text{Cov}(rp2, p2) &= \frac{rr2(rr2 + or2)\text{Var}(rr2)}{rn2(rn2 + on2)rr2(rr2 + or2)} \\ &= \frac{\text{Var}(rr2)}{rn2n2} \end{aligned}$$

and

$$\text{Cov}(rp2, p2) = \frac{rr2(rn2 - rr2)}{rn2^2 n2}.$$

so,

$$\text{Var}(rr2) = \frac{rr2(rn2 - rr2)}{rn2}$$

From (5) we have,

$$\begin{aligned} \text{Var} \left[\ln \left(\frac{p_1 r p_2}{p_2} \right) \right] &= \frac{n_1^2}{r_1^2} \frac{r_1}{n_1^3} (n_1 - r_1) + \frac{r n_2^2}{r r_2^2} \frac{r r_2}{r n_2^3} (r n_2 - r r_2) + \frac{n_2^2}{r_2^2} \frac{r_2}{n_2^3} (n_2 - r_2) \\ &\quad - \frac{2 r n_2 n_2}{r r_2 r_2} \frac{r r_2 (r n_2 - r r_2)}{r n_2^2 n_2} \\ &= \frac{n_1 - r_1}{r_1 n_1} + \frac{r n_2 - r r_2}{r r_2 r n_2} + \frac{n_2 - r_2}{r_2 n_2} - \frac{2(r n_2 - r r_2)}{r_2 r n_2}. \end{aligned}$$

Substituting into (4) we have,

$$\text{Var} \left(\frac{p_1 r p_2}{p_2} \right) = \left(\frac{p_1 r p_2}{p_2} \right)^2 \left(\frac{n_1 - r_1}{r_1 n_1} + \frac{r n_2 - r r_2}{r r_2 r n_2} + \frac{n_2 - r_2}{r_2 n_2} - \frac{2(r n_2 - r r_2)}{r_2 r n_2} \right).$$

Substituting into (3) gives,

$$\text{Var}(\hat{Y}) = \sum_{i,j,k,t} K_t^2 C_{t,i,j}^2 N_{i,j}^2 \left(\frac{p_1 r p_2}{p_2} \right)^2 \left(\frac{n_1 - r_1}{r_1 n_1} + \frac{r n_2 - r r_2}{r r_2 r n_2} + \frac{n_2 - r_2}{r_2 n_2} - \frac{2(r n_2 - r r_2)}{r_2 r n_2} \right).$$

So, from (1),

$$\text{Var}(NBA) = C_1^2 \text{Var}(\hat{Y}).$$

The 95% confidence interval is,

$$NBA \pm 1.96 \sqrt{\text{Var}(NBA)}$$

assuming that Y, the total number of shares, is approximately normally distributed.