Report to the Public Health Funding Sub-Committee of the Capacity Review Committee

The Relationship between Public Health Unit Budgets in Ontario and Indicators of Need for Public Health

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1. Introduction

This study was commissioned by the Public Health Funding Sub-Committee of Ontario's Public Health Capacity Review Committee, Ministry of Health and Long-Term Care (MOHLTC). The work is intended to support the development of a new funding approach for public health for the Province of Ontario. The specific objective of this study is to assess the relationship between Public Health Unit (PHU) budgets in Ontario and indicators of need for public health services in PHUs. As such, it is intended to provide information regarding the extent to which historical funding approaches may have resulted in funding patterns inconsistent with the principle of funding according to need.

The analysis is based on PHU budgets for three years: 1999, 2002 and 2004. The analysis uses multi-variate methods to assess the relationship between PHU funding per capita and a set of indicators of potential need for public health services (also measured at the PHU-level), including health status measures, vital statistics, socio-economic and demographic characteristics of the population. Limited data availability, measurement problems, and the nature of the underlying processes that generate many of the needs indicators create substantial challenges to inferring the relationship between specific indicators of need and PHU funding. The analysis, however, provides new insight into the relationship between the measured set of needs-indicators and PHU funding.

The key findings are as follows:

- Important unmeasured characteristics influence funding levels in a number of PHUs. These unmeasured characteristics likely include both need-related factors and non-need-related factors.
- The relationships between specific need indicators and PHU funding can be estimated only with considerable imprecision
- As a group, needs indicators explain about 50-70% of variation in PHU funding. There is a suggestion that the association between needs indicators and PHU funding decreased over the period 1999-2004.

2. Data Description and Availability.

Gathering the data necessary for the analysis posed considerable challenges. The primary sources of data were the MOHLTC, the Canadian census, and the Ontario components of national health surveys. Annual PHU budget information was available for 1999-2004. Census information is available based on the 1996 and 2001 Canadian censuses. National health surveys with over-sampling in Ontario (to allow inference to sub-provincial regions) were conducted in 1996/97 (National Population Health Survey [NPHS]), 2000-01 (Canadian Community Health Survey [CCHS], Cycle 1.1) and 2002-03 (CCHS 2.1). PHU-specific MOHLTC data varied by year.

For reasons described in more detail in the methods section, to assess the relationship between need and funding it is appropriate to use needs-indicators from a year prior to the budget year being analysed. Given the data constraints, we analyse three budget years, 1999, 2002, and 2004 using the following data:

1999 PHU budgets: 1996 Census, 1996/97 NPHS, available MOHLTC data
2002 PHU budgets: 2001 Census, 2000-01 CCHS, available MOHLTC data
2004 PHU budgets: 2002-03 CCHS, available MOHLTC data

Where available, census-derived measures (based on the entire population) were preferred to measures derived from surveys (based only on a sample).

Table 1 provides a description of all variables used in the analysis; Table 2 presents descriptive statistics on each variable. Appendix 1 provides additional detail on the construction of the variables. The tables use the following naming convention: a variable name is followed by (underscore) year and by (underscore) source of data, where:

_YY indicates the year of dataset from which the variable is constructed (96, 01 or 03);
_s indicates that the variable is derived from survey data;
_c indicates that the variable is from Census data.

For example, smoker_96_s means that this variable is derived from 1996-97 NPHS survey data; smoker_96_c means that this variable is derived from the 1996 census.

Table 1. Description of Variables Included in the Analysis, 1999, 2002 and 2004 Budget Years

Variable Name	Variable Description	Source of data
Dependent variable		
phu_capita_YY	PHU Budget per Capita, calculated as ratio of PHU Budget and PHU population estimate	MOHLTC
Independent variables		
Population Health Characteristics		
sahs_YY_s	Percent of PHU population in fair/poor health	NPHS 96-97, CCHS 1.1, CCHS 2.1
bmi_YY_s	Percent of PHU population that is overweight/obese	NPHS 96-97, CCHS 1.1, CCHS 2.2
Health-Related Behaviours		
smoker_YY_s	Percent of population that smokes daily	NPHS 96-97, CCHS 1.1, CCHS 2.1
alc_YY_s	Percent of population that drinks => 5 drinks on one occasion, => 12 times per year	NPHS 96-97, CCHS 1.1, CCHS 2.2
Vital Statistics		
low_w_babies_YY	Percent of live births that are of low weight (<2500 g)	CANSIM
infant_m_YY	Infant mortality (deaths/1000 live births)	CANSIM
perinatal_m_YY	Perinatal Mortality (rate per 1000 total births)	CANSIM
life_exp_YY	Life Expectancy at Birth, total	CANSIM
mortality_10_YY	Total mortality (age-standardized rate per 100,000 population), rescaled (divided by 10)	CANSIM
pyll_1000_YY	Potential years of life lost (rate per 100,000 population), total, rescaled (divided by 1000)	CANSIM
Socio-Economic Characteristics		
high_sch_YY_s	Percent of high school graduates, aged 25 to 59	NPHS 96-97, CCHS 1.1, CCHS 2.2
ef_lico_YY_c	Percent of economic families with household income below the Low Income Cut-Off	Census 1996, 2001
ph_lico_YY_c	Percent of people in private households with household income below Low Income Cut-Off	Census 1996, 2001
ph_lico_YY_s	Percent of population with income below Low Income Cut Off (LICO), analogous to Census Incidence of Low Income	NPHS 96-97, CCHS 1.1, CCHS 2.2
imm_15_96_c	Recent immigrants (live in Canada for 15 years or less) as percent of total population	Census 1996
imm_10_01_c	Recent immigrants (live in Canada for 10 years or less) as percent of total population	Census 2001
aboriginal_YY_inac	Aboriginals (on-reserve and off-reserve) as percent of total population	Indian and Northern Affairs Canada (INAC)
lone_YY_c	Lone-parent families as percent of all private households	Census 1996, 2001
unempl_lt_YY_c	Long-term unemployment rate	CANSIM
unempl_YY_st_c	Unemployment rate	CANSIM
density_YY_c	Population density (people per sq km)	Census 1996, 2001

Variable Name	Variable Description	Source of data
rural_YY_c	Percent of population living in rural area	Census 1996, 2001
rural_YY_s	Percent of population living in rural area	NPHS 96-97, CCHS 1.1, CCHS 2.2
dwell_1000_YY	Average dwelling value	Census 1996, 2001
Other PHU Characteristics		
high_fp_p_YY	Number of high-risk food premises (excluding seasonal premises)	MOHLTC
total_fp_p_YY	Number of total food premises (excluding seasonal premises)	MOHLTC
high_fp_pt_YY	Number of high-risk food premises (including seasonal premises)	MOHLTC
total_fp_pt_YY	Number of total food premises (including seasonal premises)	MOHLTC
governance	Type of board of health: same across budget years 0 - autonomous type of board of health, 1 - regional councils and single-tier municipalities, Toronto PHU	MOHLTC

Notes: YY refers to the year in which the variable was measured (e.g., 1996, 2001, 2003)
c – variable measures using census data;
s – variable measured using health survey data

Table 2. Descriptive Statistics of Variables in the Model, 1999, 2002 and 2004 Budget Years

	1999 Budget Year				2002 Budget Year				2004 Budget Year			
Variable	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
phu_capita_YY	32.19	8.55	19.29	58.78	40.01	11.36	22.61	64.68	45.79	12.01	28.16	72.10
Health Characteristics												
sahs_YY_s	9.54	2.01	5.81	14.73	13.08	2.56	8.99	18.10	12.88	2.40	8.80	18.92
bmi_YY_s	51.46	4.73	40.45	62.48	53.62	4.21	39.56	59.03	54.99	5.55	41.44	64.24
Health-Related Behaviours												
smoker_YY_s	19.68	2.96	13.79	27.96	22.61	3.56	16.12	32.80	19.15	2.96	13.49	26.32
alc_YY_s	16.88	2.46	10.72	21.55	21.96	3.23	13.73	28.15	23.43	3.18	16.40	30.67
Vital Statistics												
low_w_babies_YY	5.64	0.59	4.50	6.80	5.29	0.57	4.10	6.60	N/A	N/A	N/A	N/A
infant_m_YY	5.91	1.38	3.90	9.80	5.56	1.23	3.40	8.00	N/A	N/A	N/A	N/A
perinatal_m_YY	6.88	1.32	4.40	9.30	6.28	1.46	4.20	10.40	N/A	N/A	N/A	N/A
life_exp_YY	77.89	1.26	74.20	80.60	78.85	1.28	75.50	81.60	N/A	N/A	N/A	N/A
mortality_100_YY	7.03	0.63	5.72	8.60	6.46	0.66	5.16	7.95	N/A	N/A	N/A	N/A
pyll_1000_YY	5.85	1.09	3.61	9.67	5.47	1.03	3.28	8.25	N/A	N/A	N/A	N/A
Socio-Economic Characteristics												
high_sch_YY_s	76.38	5.69	62.69	87.10	79.26	5.54	65.72	90.53	92.60	2.35	87.08	96.60
ph_lico_YY_c	14.71	3.57	9.30	27.60	12.33	3.48	7.10	22.60	N/A	N/A	N/A	N/A
ph_lico_YY_s	22.40	5.64	7.33	33.85	20.56	5.03	9.83	32.52	16.09	3.85	8.64	23.55
imm_15_c	4.39	5.35	0.42	25.23	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
imm_01_c	N/A	N/A	N/A	N/A	3.34	4.61	0.30	21.03	N/A	N/A	N/A	N/A
aboriginal_YY_inac	3.46	6.76	0.00	35.54	3.69	7.26	0.00	38.32	3.79	7.51	0.00	39.82
lone_YY_c	13.01	2.12	8.70	18.90	13.88	2.15	9.80	19.70	N/A	N/A	N/A	N/A
unempl_lt_YY_c	2.93	0.74	1.50	4.80	3.22	1.07	1.70	5.70	N/A	N/A	N/A	N/A
unempl_st_YY	9.39	1.93	5.30	14.10	6.46	1.60	3.70	11.80	6.51	1.13	4.40	8.70
density_YY_c	204.11	623.88	0.35	3785.84	217.27	651.53	0.32	3939.35	223.27	657.54	0.00	3960.00
rural_YY_c	31.01	18.63	0.00	67.40	30.54	19.03	0.00	67.10	N/A	N/A	N/A	N/A
rural_YY_s	19.35	11.97	0.00	53.24	24.93	15.49	0.00	61.78	28.01	17.90	0.00	61.13
dwell_1000_YY	146.28	39.00	89.01	279.39	158.19	48.08	88.49	298.02	163.35	52.35	88.28	305.82
Other PHU Characteristics												
high_fp_p_YY	465.78	539.93	53.00	2765.00	451.95	665.12	37.00	3849.00	483.22	769.86	31.00	4510.00
total_fp_p_YY	2233.68	3072.63	474.00	18695.00	2096.68	2987.18	393.00	18010.00	2126.73	2805.20	327.00	16599.00
high_fp_pt_YY	N/A	N/A	N/A	N/A	475.97	662.97	37.00	3849.00	530.95	794.92	31.00	4651.00
total_fp_pt_YY	N/A	N/A	N/A	N/A	2243.16	2968.07	457.00	18010.00	2310.57	2864.36	424.00	17096.00

2.1 Dependent Variable.

The dependent variable is defined as the total (including both the local and the provincial contributions) PHU budget per capita. This is derived by dividing the PHU budget for the relevant year by the PHU population in that year. For 1999, 2002 and 2004, the PHU-level population figures are the inter-censal population estimates. These estimates include Aboriginals living off-reserve as well as at least some Aboriginals living on-reserve. There are thirty seven Indian reserves and Indian settlements in Ontario that are considered to be incompletely enumerated in Census. In these reserves and settlements enumeration was either not permitted or was interrupted before it could be completed. There is no simple way to adjust quantitatively for the enumeration problems with on-reserve Aboriginal populations, so there is likely some measurement error in the population estimates.

The mean level of funding per capita across the PHUs was \$32.19, \$40.01, and \$45.79 respectively in 1999, 2002 and 2004. Within each year there was considerable variation across PHUs in per-capita. In 2002, for example, funding per capita varied from \$22.61 to \$64.68. This variation, however, provides no insight into the appropriateness of funding patterns as it may or may not be consistent with variation in needs across PHUs.

2.2 Independent Variables.

Potential needs indicators were identified by the researchers and by members of the public health funding sub-committee. Each was measured at the PHU level. The indicators can be grouped into population health characteristics, health-related behaviours, vital statistics, socio-economic and demographic characteristics, and miscellaneous indicators of need. Most of the indicators are self-evident, as they represent an indicator of need for public health services. Few deserve comment. The analysis should also to control for factors that influence the costs of providing a given public health service. Population density and degree of rurality may reflect in part such cost considerations. Dwelling value is included specifically to reflect differences in cost of living across PHUs, which should be correlated with PHU costs (e.g., salary, rent). It may also represent general level of wealth in the PHU.[1]

3. Methods

The unit of analysis is a PHU. The study uses multi-variate regression analysis to assess the relationship for the years 1999, 2002 and 2004 between per-capita funding to each of Ontario public health units and a series of need indicators (also measured at the PHU level), including health status measures, vital statistics, socio-economic and demographic characteristics of the population. That is, for each of the 37 PHUs we have three annual observations, for a total of 111 observations in the sample. Repeated observations on each PHU, or the panel of observations, allows us to control better for unobserved characteristics of each region that do not change over time.

Four basic estimation methods are possible (Table 3). The methods differ with respect to the assumptions they make regarding the underlying relationship between the needs indicators and funding levels, between the presence of important unmeasured aspects of the PHUs that influence PHU funding, the relationship between any such unmeasured factors and the measured needs-indicators, and the type of variation in the data on which the parameter estimates are based. There is no reason to prefer one model over another *a priori*. We estimated models based on each method, and tested where possible the validity of the assumptions underlying each model.

[1] We experimented with a salary index to represent PHU costs (most of which are personnel). The salary information was not available in all years, however. Furthermore, it is possible that salary levels reflect generosity of funding. For this reason, we opted to use dwelling value.

Table 3: Alternative Estimation Methods for the Three-year Panel of PHU Data

Estimation Method	Key Features and Assumptions
Pooled Ordinary Least Squares (OLS)	• Pools the data across all 111 observations (37 x 3) to estimate a single model of the relationship between need and funding • Exploits variation both across PHUs in a given year and variation across years within each PHU to estimate model parameters • Assumes that the relationship between need characteristics and funding was constant both across PHUs and across time • Assumes that there are no unmeasured PHU characteristics that influence the funding received by the PHU and that are correlated with individual variables
Separate OLS regressions on each annual cross-section	• Estimates three separate models of the relationship between need and PHU funding; one for each year • Allows the relationship between need characteristics and funding to differ across years • Each model exploits only variation across PHUs in that year to estimate model parameters • Assumes that there are no unmeasured PHU characteristics that influence the funding received by the PHU
Fixed-Effects Model	• Uses all 111 observations to estimate a single model of the relationship between need and funding • Exploits only variation across years within each PHU to estimate model parameters; it does not use any information on variation across PHUs • Allows the intercept terms to vary across PHUs • Assumes that unmeasured characteristics of PHUs influence PHU funding and allows these unmeasured characteristics to be correlated with the measured characteristics
Random-Effects Model	• Uses all 111 observations to estimate a single model of the relationship between need and funding • Exploits variation both across years within each PHU and across PHUs in a given year to estimate model parameters • Allows the intercept terms to vary across PHUs • Assumes that unmeasured characteristics of PHUs influence PHU funding but that these unmeasured characteristics are not correlated with the measured characteristics

For a general introduction to these models, see Wooldridge (2003); for a more advanced treatment, see Wooldridge (2002)

Two additional methodological issues deserve mention: two-way causality and multi-collinearity. The analysis explores the extent to which needs influence budget levels. But the causal relationship may go in both directions. The level of funding can influence measured levels of a need indicator. For example, reduced funding in a given year may increase STD rates in that year. Such two-way causality causes regression coefficients to be biased. To minimize the potential for such bias, we use prior-year need-indicators to explain variation in subsequent PHU budget per capita. Needs-indicators derived from the 2001 census, for example, are used in the analysis of 2002 PHU budgets. This avoids bias because while it is plausible that 2001 need levels can influence 2002 budget allocations, it is not possible for 2002 budget allocations to have influenced levels of need in 2001.

Second, a high degree of collinearity, or correlation, exists among the various needs-indicators. The collinearity has three important implications for the analysis and the interpretation of the results:

- collinearity introduces an unavoidable degree of arbitrariness in which variables remain in the final specifications. Other specifications with different, but highly correlated, need indicators may do almost as well in explaining budget variation.
- Many of the individual needs-indicators will not be statistically significant in the regression model, although the indicators as a group do explain a significant amount of variation.
- Each variable in the final model may reflect the influence of a number of factors with which it is highly correlated.

Although collinearity frustrates efforts to assess the relationship between individual need indicators and funding (so that we must be cautious in interpreting the coefficient estimates in individual variables), it does not compromise our ability to assess the extent of the relationship between needs indicators as a whole and levels of funding. We assess the extent to which the needs indicators explain variation in budgets using R^2 measures. In ordinary-least squares models we focus in particular on the adjusted-R^2 measure, which takes into account the number of independent variables included in the model.[2] As we discuss below, comparing R^2 across the various models is not always straightforward, so again, some caution is needed.

Because there are only thirty seven PHUs in Ontario, there is a relatively small number of observations each year. Combined with only three years of data, this means that we seek relatively parsimonious specifications of need-indicators. The analysis assessed the models using standard diagnostic tests for regressions, including tests for heteroskedasticity and collinearity.

4. Results

The analysis proceeded first by assessing the simple bi-variate relationship between the various needs indicators and PHU funding, and then assessed the multi-variate relationship.

4.1. Bivariate Correlation Analysis.

Bivariate correlation analysis measures the correlation between a single need indicator and the budget per capita. No other factors are taken into consideration. The closer is the correlation coefficient to one or minus one, the stronger is the (unadjusted) relationship between two factors.

Table 4 lists the bivariate correlation coefficients between independent variable and PHU budget per capita in the corresponding year. We note three patterns. First, a subset of the indicators is highly correlated with per-capita funding across all three years. Strongly correlated (over 0.60 each year) indicators include vital statistics such as life-expectancy, mortality and potential life-years lost, and education levels. Moderate (0.40 - 0.60) stable correlations are present for self-assessed health status, smoking rates, the proportion of the population that is aboriginal, survey-based measures of low income, and dwelling values[3]. Other indicators, such as obesity levels as measured by the BMI, unemployment levels, and degree of rurality, have highly unstable correlations across the

[2] This is particularly important given the small number of observations. The addition of a variable to a model always increases the unadjusted R^2. In contrast, the adjusted-R^2 measure only increases if the variable adds important ability to explain variation in budgets.

[3] The negative correlation for dwelling values suggests that the dominate relationship may reflect more wealth levels than costs of living.

years. Finally, the remaining indicators appear to be relatively weakly correlated with PHU funding.

All characteristics with strong or moderate correlation coefficients have anticipated direction of relationship with PHU budget per capita. Weakly correlated indicators such as percent of low weight births, percent of population less than 15 years old and public health inspection characteristics have negative coefficients, which is unexpected. However, these correlation coefficients are not significant.

Table 4. Bivariate Correlation Between the PHU Budget per Capita and Independent Variables, 1999, 2002 and 2004 Budget Years

	Budget Year 1999		Budget Year 2002		Budget Year 2004	
Variable	Correlation Coefficient	p-value	Correlation Coefficient	p-value	Correlation Coefficient	p-value
sahs	0.464	0.00	0.538	0.00	0.548	0.00
bmi	0.702	0.00	0.430	0.01	0.453	0.00
smoker	0.456	0.00	0.578	0.00	0.533	0.00
alc	0.210	0.21	0.318	0.05	0.464	0.00
low_w_babies	-0.068	0.69	-0.245	0.14	N/A	N/A
infant_m	0.337	0.04	0.200	0.24	N/A	N/A
perinatal_m	-0.049	0.77	0.082	0.63	N/A	N/A
life_exp	-0.764	0.00	-0.653	0.00	N/A	N/A
mortality_10	0.738	0.00	0.684	0.00	N/A	N/A
pyll_1000	0.785	0.00	0.696	0.00	N/A	N/A
high_sch	-0.657	0.00	-0.628	0.00	-0.671	0.00
ef_lico_c	0.127	0.45	0.274	0.10	N/A	N/A
ph_lico_c	0.146	0.39	0.294	0.08	N/A	N/A
ph_lico_s	0.410	0.01	0.546	0.00	0.444	0.01
imm_15_96_c	-0.374	0.02	N/A	N/A	N/A	N/A
imm_10_01_c	N/A	N/A	-0.371	0.02	N/A	N/A
aboriginal_inac	0.593	0.00	0.471	0.00	0.422	0.01
lone_c	0.153	0.37	0.095	0.58	N/A	N/A
unempl_lt_c	0.153	0.37	0.712	0.00	N/A	N/A
unempl_st_c	0.562	0.00	0.438	0.01	0.254	0.13
density_c	-0.059	0.73	-0.101	0.55	-0.129	0.45
rural_c	0.366	0.03	0.381	0.02	N/A	N/A
rural_s	0.221	0.19	0.281	0.09	0.489	0.00
high_fp_p	-0.231	0.17	-0.142	0.40	-0.167	0.32
total_fp_p	-0.152	0.37	-0.172	0.31	-0.254	0.13
high_fp_pt	N/A	N/A	-0.137	0.42	-0.154	0.36
total_fp_pt	N/A	N/A	-0.165	0.33	-0.239	0.15
dwell_1000	-0.558	0.00	-0.504	0.00	-0.511	0.00
governance	-0.389	0.02	-0.363	0.03	-0.444	0.01

4.2. Multi-variate Regression Analysis.

It was important to reduce the number of variables in the model for three reasons: (1) the full set of variables is larger than can reasonably be included in the analysis (given the small sample); (2) many of the variables represent closely related conceptual factors (e.g., alternative mortality-related measures); (3) some variables are not available all years. We initially tested relatively inclusive models and removed variables based on a combination of conceptual criteria (another measure could represent the construct) and statistical criteria (removing the model increased adjusted R-squared). We did not strive to derive the most parsimonious model possible; where possible we retained at least one variable from each conceptual category of needs-indicators. As noted, in the presence of collinearity there is unavoidably a certain degree of arbitrariness in the variables that are retained based on statistical criteria. For this reason, our discussion does not emphasize individual parameter estimates, though we will offer some comment on these aspects of the estimates.

Table 5 lists the results of the multivariate analyses that use the full sample to estimate the need-funding relationship. We consider first the fixed-effects model. The most important finding from this model is that unobserved, fixed factors about several PHUs are associated with PHU funding, and that these unobserved factors are correlated with the needs indicators included in the analysis. These unmeasured characteristics of PHUs likely include both need-related factors (e.g., total number of inspection sites, special unmeasured needs) as well as non-need related factors (willingness of a local municipality to fund public health; effectiveness of the local Medical Officer in advocating for funding; historical legacy, etc). In the presence of such unmeasured factors, the coefficient estimates on the needs indicators in the random effects model and the pooled-OLS model are biased, and the p-values in the pooled-OLS model are underestimated.

Table 5: Results for Fixed Effect, Pooled OLS and Random Effects Models

	Fixed Effects						Pooled OLS		Random Effects	
Number of obs	111						111		Number of obs	111
Prob > F	0.00						0.00		Prob > chi2	0.00
R-squared	0.94						0.64		R-squared	0.57
Adj R-squared	0.90						0.59			
Variable	**Coeff**	**p-value**	**Variable**	**Coeff**	**p-value**		**Coeff**	**p-value**	**Coeff**	**p-value**
sahs_s	-0.151	0.70					**0.846**	**0.07**	0.395	0.28
bmi_s	-0.179	0.37					0.038	0.90	-0.047	0.81
smoker_s	0.321	0.22					0.174	0.65	0.307	0.24
alc_s	-0.169	0.52					0.064	0.85	-0.271	0.28
high_sch_s	0.060	0.71					**-0.645**	**0.00**	-0.115	0.45
ph_lico_s	-0.233	0.30					**0.505**	**0.05**	0.107	0.58
aboriginal_inac	-0.259	0.85					**0.455**	**0.00**	**0.486**	**0.01**
unempl_st	-0.197	0.69					0.076	0.91	-0.001	1.00
rural_s	-0.083	0.36					**0.107**	**0.08**	0.062	0.35
dwell_1000	**-0.117**	**0.08**					0.034	0.34	**-0.063**	**0.08**
year_2001	**9.395**	**0.00**					5.805	0.13	**7.819**	**0.00**
year_2003	**15.806**	**0.00**					**22.509**	**0.00**	**17.296**	**0.00**
_cons	**60.543**	**0.01**					46.261	0.12	**42.105**	**0.05**
phu_Kent_Cht	2.487		phu_Huron	0.247	0.76					
phu_King_Fr	-3.573	0.42	phu_Simcoe	**-10.252**	**0.06**					
phu_Lambt	**-7.914**	**0.01**	phu_Sudbury	**17.291**	**0.01**					
phu_Leeds_Gren	-7.634	0.16	phu_Thunder_B	1.478	0.88					
phu_Mid_Lond	**-12.863**	**0.06**	phu_Timisk	**21.045**	**0.00**					
phu_Musk_PS	**19.616**	**0.00**	phu_Wat	-5.735	0.30					
phu_Niag	-6.783	0.21	phu_Well_Duff	-5.017	0.38					
phu_North_Bay	**18.132**	**0.00**	phu_Wind_ess	**-15.109**	**0.02**					
phu_Northwest	25.805	0.60	phu_York	3.889	0.91					
phu_Algoma	5.994	0.44	phu_Toronto	13.547	0.33					
phu_Brant	0.216	0.90	phu_Ottawa	-9.773	0.16					
phu_Durham	-6.016	0.32	phu_Oxford	-3.837	0.37					
phu_Elgin_ST	3.849	0.85	phu_Peel	-9.360	0.24					
phu_Bruce_Grey	-2.281	0.37	phu_Perth	2.141	0.97					
phu_Hald_Norf	-6.882	0.20	phu_Peterb	**-8.821**	**0.06**					
phu_Halib	7.797	0.44	phu_Porcup	20.242	0.24					
phu_Halton	-4.007	0.58	phu_Renfr	3.972	0.79					
phu_Ham	-3.776	0.40	phu_East_Ont	**-4.715**	**0.05**					
phu_Hast_PE	1.687	0.82								

Note: Bold indicates that the parameter estimate is statistically significant at the 10% level.

The estimates of these PHU-specific unmeasured factors are presented at the bottom of the table. They indicate the extent to which, controlling for everything else in the model, the PHUs funding consistently differs from the provincial norm.[4] The coefficient for Lambton PHU, for instance, means that, controlling for all other factors, Lambton PHU receives $7.91 per capita less than the provincial norm.[5] Some of these PHU-specific effects are quite large.

The parameter estimates for the needs-indicators themselves suffer from considerable imprecision. As noted, the fixed-effects model uses only variation across years within each PHU to estimate model parameter. Unfortunately, in our situation, most of the needs-indicators changed very little over the study period. Consequently, the small amount of variation over time in the needs indicators, together with collinearity, produces very imprecise parameter estimates in the fixed effects model. Virtually none of the needs-indicators are statistically significant. Only the variable for the value of owner-occupied dwellings is statistically significant with a negative sign. As expected, each of the year dummies (year_2001 and year_2003) are significant, and reflect the overall increase in public health funding over this period.

The random effects model, which also incorporates such unobserved PHU-specific effects (but which does not report parameter estimates for them) similarly finds only weak and imprecise estimates of the effect between specific needs indicators and PHU funding. The pooled-OLS results include more statistically significant variables than the other two models. The proportion of the population in poor or fair health, the proportion of households below the low-income cut-off, the proportion of aboriginal population, and the proportion of the population that is rural are all positively associated with PHU funding, while the proportion of the population aged 25-59 that has completed high school is negatively related to PHU funding. These patterns are consistent with expectations, but the specific quantitative relationship must be interpreted with caution since presence of the unobserved factors causes the pooled-OLS estimates to be biased

[4] That is, the coefficients on the PHU variables that reflect these effects have been normalized to represent deviations from the provincial mean (Kennedy 1998).

[5] The table of correspondence of PHU acronyms to PHU names is enclosed in Appendix 2.

and the standard errors are underestimated, suggesting statistical significance where it is not actually present.

In terms of overall explanatory power, for both the pooled-OLS model and the random effects model the needs-indicators explain just under 60% of the variation in PHU funding during these three years. The very high adjusted-R^2 for the fixed effects model (0.90) does not represent the explanatory power of the needs-indicators as it includes the effects of the unobserved factors. Hence, the R^2 measures from the random effects model and the pooled-OLS model are better indicators of the ability of needs-indicators to explain variation in PHU funding per capita.

Table 6 presents the results of the three separate cross-sectional regression models for each budget year. The table contains two sets of results. For consistency with the results in Table 5 and to facilitate comparison across the years, panel A presents results when the models include only variables that are consistently defined across all three years; panel B exploits the best available data in any given year, which leads to different variable specifications across the years. Focusing first on panel A, the pattern is generally one of non-significant individual variable coefficients, reflecting the imprecision in estimates given collinearity and small sample sizes. The proportion of the population aged 25-59 with a high school education is consistently found to be negatively associated with PHU funding, though the point estimate of this effect is very unstable. The results also suggest a positive association between the proportion of the population that is aboriginal and PHU funding. Again, there is potential for bias in these estimates due to omitted, unobserved factors correlated with the included variables.

The needs indicators explain just under 55% of variation in PHU funding in 1999 and 2002 (adjusted-R^2 are 0.54 and 0.53 respectively); the ability of needs-indicators to explain variation in PHU funding is notably less in 2004, for which the adjusted-R^2 is 0.45.

In panel B we are able to include more needs-indicators for the 1999 and 2002 budget years because census data were available for 1996 and 2001 respectively. The most important thing to note is that the adjusted-R^2 values do increase, to 0.72 in 1999 and 0.61 in 2002.

Table 6: Results of Cross-sectional Regression Analysis on 1999, 2002 and 2004 Budget Years

Dependent Variable: PHU Budget Per Capita in the Corresponding Budget Year												
	Panel A						**Panel B**					
	1999		**2002**		**2004**		**1999**		**2002**		**2004**	
Number of obs	37		37		37		37		37		37	
Prob > F	0.00		0.00		0.00		0.00		0.00		0.00	
R	0.67		0.66		0.60		0.82		0.75		0.60	
Adj R	0.54		0.53		0.45		0.72		0.61		0.45	
Variable	**Coeff**	**p-value**	**Coeff**	**p-value**	**Coeff**	**p-value**	**Coeff**	**p-value**	**Coeff**	**p-value**	**Coeff**	**p-value**
sahs_YY_s	0.648	0.43	0.102	0.90	1.334	0.19	-0.933	0.25	-0.265	0.73	1.334	0.19
bmi_YY_s	**0.724**	**0.09**	-0.465	0.56	-0.018	0.98	**1.143**	**0.03**	-0.047	0.95	-0.018	0.98
smoker_YY_s	-0.675	0.36	0.714	0.23	-0.233	0.83	-0.236	0.70	0.277	0.62	-0.233	0.83
alc_YY_s	0.298	0.59	0.204	0.73	0.501	0.53	**0.898**	**0.06**	-0.678	0.30	0.501	0.53
infant_m_YY	N/A	N/A	N/A	N/A	N/A	N/A	**-2.447**	**0.04**	0.641	0.63	N/A	N/A
pyll_1000_YY	N/A	N/A	N/A	N/A	N/A	N/A	3.851	0.21	1.523	0.73	N/A	N/A
high_sch_YY_s	**-0.541**	**0.08**	**-0.884**	**0.03**	**-2.009**	**0.07**	**-0.566**	**0.02**	**-1.039**	**0.01**	**-2.009**	**0.07**
ph_lico_YY_c	N/A	N/A	N/A	N/A	N/A	N/A	0.909	0.17	0.679	0.44	N/A	N/A
ph_lico_YY_s	0.001	1.00	**1.112**	**0.04**	0.787	0.31	N/A	N/A	N/A	N/A	0.787	0.31
imm_15_96_c	N/A	N/A	N/A	N/A	N/A	N/A	0.416	0.33	N/A	N/A	N/A	N/A
imm_10_01_c	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	-1.268	0.10	N/A	N/A
rec_imm_YY_s	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
aboriginal_YY_inac	0.264	0.32	**0.582**	**0.01**	**0.417**	**0.10**	0.190	0.42	0.133	0.67	**0.417**	**0.10**
unempl_lt_YY_c	N/A	N/A	N/A	N/A	N/A	N/A	-0.043	0.98	**6.413**	**0.02**	N/A	N/A
unempl_st_YY	1.039	0.23	-0.361	0.79	-0.250	0.91	N/A	N/A	N/A	N/A	-0.250	0.91
rural_YY_c	N/A	N/A	N/A	N/A	N/A	N/A	0.042	0.56	0.095	0.44	N/A	N/A
rural_YY_s	-0.030	0.79	0.173	0.12	0.171	0.16	N/A	N/A	N/A	N/A	0.171	0.16
dwell_1000_YY	0.031	0.63	0.086	0.23	0.075	0.29	0.046	0.43	**0.190**	**0.04**	0.075	0.29
_cons	23.702	0.54	72.443	0.30	178.595	0.13	-16.906	0.59	66.781	0.34	178.595	0.13

Note: Bold indicates that the parameter estimate is statistically significant at the 10% level.

Finally, we should note the results of an analysis not presented in Tables 5 and 6. One might expect PHU-funding per capita to be related to PHU population because of the presence of indivisibilities in costs. For example, if every PHU has a medical officer of health, the salary costs will be spread over fewer people in a small PHU. Similarly, other costs (certain information campaigns) do not vary with population size. The presence of these types of fixed costs, which do not vary with population size (or which vary little) would lead small PHUs, other things equal, to have higher costs per capita. On the other hand, large PHUs may experience higher costs because of the complexity of their organizations increases costs per capita. To assess the relationship between funding per capita and PHU population, we tested a specification that included variables representing the PHU population and the square of PHU population.[6] In all such specifications the population variables were not statistically significant. Although not a definitive test, the results suggest that such size-related cost considerations are not important in explaining variation in PHU funding per capita.

5. Discussion.

The key findings from this analysis are that:

- Important data constraints limit our ability to assess the relationship between public health needs and public health funding.
- The high degree of correlation among the included need indicators, together with their relatively slow rate of change over time, make it difficult to identify the association between individual needs indicators and public health funding.
- A number of currently unmeasured, fixed (i.e., constant across time) aspects of PHUs are associated with variation in PHU funding. These unmeasured factors likely include both unmeasured needs-related factors as well as unmeasured non-need factors.
- As a group, needs indicators explain between 50 and 70 percent of variation in PHU funding in Ontario during the three years included in this study. Of concern is the

[6] This allows for a non-linear relationship between population and costs per capita, with higher costs for both very small PHUs and very large PHUs, and lower costs for medium-sized PHUs.

suggestion in these results that the association between variation in needs indicators and variation in PHU funding has fallen between 1999 and 2004.

This work highlights some of the challenges faced in developing funding formula for public health. There is a large literature on developing needs-based funding formulae for health care. Health care programs, however, differ in some important ways from public health. Many public health programs are targeted at populations rather than individuals. Hence, there is very limited individual-level data on which to base formula development. While it is easy to identify public health needs-indicators that command widespread support, it is a far greater challenge to quantify the relationship between such indicators and need for public health funding. Many jurisdictions simply assume a quantitative relationship between indicators and need for funds (e.g., it is often assumed to be linear) and the weight each indicator receives in the formula. In the absence of validation, however, it is not possible to know if such formulae do any better than current funding arrangements. Further work is required to assess what is feasible given data available in Ontario and to assess what role a funding formula can play within the overall approach to funding public health in Ontario.

Appendix 1. Description and Availability of Data						
Variable	**Description of variable**	**Variable Name** [1]	**Availability**			**Source of data if available**
			1996	**2001**	**2003**	
Dependent Variable						
Budget per Capita	PHU Budget per Capita, calculated as ratio of PHU Budget and PHU population estimate	phu_capita_YY	√	√	√	MOHLTC
Independent Variables						
Population Health Characteristics						
Self-rated health	Percent of PHU population in fair/poor health	sahs_YY_s	√	√	√	NPHS 1996/97, CCHS 1.1 & 2.1
Body Mass Index (BMI)	Percent of PHU population (aged 20 to 64 excluding pregnant women) that is overweight/obese	bmi_YY_s	√	√	√	NPHS 1996/97, CCHS 1.1 & 2.1
Health-related Behaviours						
Smoking	Percent of population that smokes daily	smoker_YY_s	√	√	√	NPHS 1996/97, CCHS 1.1 & 2.1
Alcohol	Percent of population that drinks 5 or more drinks on one occasion, 12 or more times per year	alc_YY_s	√	√	√	NPHS 1996/97, CCHS 1.1 & 2.1
Vital Statistics						
Low birth weight	Percent of live births that are of low weight (<2500 g)	low_w_babies_YY	√	√	N/A	CANSIM
Infant mortality	Infant mortality (deaths/1000 live births)	infant_m_YY	√	√	N/A	CANSIM
Perinatal mortality	Perinatal Mortality (rate per 1000 total births)	perinatal_m_YY	√	√	N/A	CANSIM
Life expectancy	Life Expectancy at Birth, total	life_exp_YY	√	√	N/A	CANSIM
Mortality	Total mortality (age-standardized rate per 100,000 population), rescaled (divided by 100)	mortality_100_YY	√	√	N/A	CANSIM

Appendix 1. Description and Availability of Data

Variable	Description of variable	Variable Name [1]	Availability 1996	Availability 2001	Availability 2003	Source of data if available
Premature mortality	Potential years of life lost (rate per 100,000 population), rescaled (divided by 1000)	pyll_1000_YY	√	√	N/A	CANSIM
Socio-Economic Characteristics						
Education	Percent of high school graduates, aged 25 to 59	high_sch_YY_s	√	√	√	NPHS 1996/97, CCHS 1.1 & 2.1
Income [2]	Percent of population with income below Low Income Cut Off (LICO), analogous to Census Incidence of Low Income	ph_lico_YY_s	√	√	√	NPHS 1996/97, CCHS 1.1 & 2.1
	Percent of population in private households with household income below the Low income cut-off	ph_lico_YY_c	√	√	N/A	Census 1996, 2001
Immigrant population [3]	Recent immigrants (live in Canada for less than 10 years) as percent of total population	rec_imm_YY_s	√	√	√	NPHS 1996/97, CCHS 1.1 & 2.1
	Recent immigrants (live in Canada for less than 10 years) as percent of total population	imm_01_c	N/A	√	N/A	Census 2001
	Recent immigrants (live in Canada for less than 15 years) as percent of total population	imm_15_c	√	N/A	N/A	Census 1996
Aboriginal population [4]	Aboriginals (on-reserve and off-reserve) as percent of total population	aboriginal_YY_inac	√	√	√	Indian and Northern Affairs Canada
Family structure [5]	Lone-parent families as percent of all private households	lone_YY_c	√	√	N/A	Census 1996, 2001
Economic conditions [6]	Long-term unemployment rate	unempl_lt_YY_c	√	√	N/A	CANSIM (Census 1996, 2001)
	Short-term unemployment rate	unempl_st_YY	√	√	√	CANSIM

Appendix 1. Description and Availability of Data						
Variable	**Description of variable**	**Variable Name** [1]	**Availability**			**Source of data if available**
			1996	**2001**	**2003**	
Density	Population density (people per sq km)	density_YY_c	√	√	√	CANSIM
Urban / rural area	Percent of population living in rural area	rural_YY_c, rural_YY_s	√	√	√	NPHS 1996/97, CCHS 1.1 & 2.1; Census 1996, 2001)
Youth [7]	Percent of population less than 15 years old	youth	√	√	Can be derived	Census 1996, 2001, CCHS 2.1
Cost of living [8]	Average dwelling value	dwell_1000_YY	√	√	√	Census 1996, 2001
	Wage index, based on Alpha survey, 2003	index_a	N/A	√	N/A	Alpha Survey; MOHLTC
Other PHU characteristics						
Governance [9]	Type of board of health	governance	√			MOHLTC
STD rates	STD rates	Available only at provincial level; this variable is not suitable for the analysis and is not included as one of the factors explaining the variation in PHU budgets				MOHLTC
Public Health Inspection [10]	Number of total food premises (including seasonal premises)	total_fp_pt	N/A	√	√	MOHLTC
	Number of total food premises (excluding seasonal premises)	total_fp_p	√	√	√	MOHLTC
	Number of high-risk food premises (including seasonal premises)	high_fp_pt	N/A	√	√	MOHLTC
	Number of high-risk food premises (excluding seasonal premises)	high_fp_p	√	√	√	MOHLTC

Notes:

[1] Variable name is followed by (underscore) year and by (underscore) source of data: _YY - year of dataset (96, 01 or 03), _s - variable is derived from survey, _c - variable is from Census. For example, smoker_96_s means that this variable is from 1996 dataset and is derived from the survey.

[2] Income: percent of population with household income below Low Income Cut Off (LICO). This variable is analogous to the Census Incidence of Low Income variable. Low income cut offs used for the present analysis were calculated using Census 1996 and 2001 matrix for low income cut offs.

[3] Immigrant population: recent immigrants as percent of total population. The definitions of recent immigrants are different in Census 1996 and 2001. In Census 1996, recent immigrants are defined as immigrants who live in Canada for 15 years or less, whereas in Census 2001 recent immigrants are defined as immigrants who live in Canada for 10 years or less. Percent of recent immigrants was derived using surveys NPHS 96/97, CCHS 1.1 and CCHS 2.1 per Census 2001 definition. However, this survey-derived variable might be unreliable due to the low sample size in some PHUs (unweighted sample size <5).

[4] Aboriginal population: percent of aboriginals in PHU. This variable is derived using data from Indian and Northern Affairs Canada (INAC). Originally counts of on-reserve and off-reserve aboriginals were available at First Nation community level from INAC. Using Postal Code Conversion File and postal code of the nearest service centre (service centre is defined as the nearest community to which a First Nation can refer to gain access to government services, banks and suppliers, as well as health services), each First Nation reserve was mapped into Public Health Unit and then information on number of on-reserve and off-reserve aboriginals was aggregated at PHU level.

[5] Family structure: lone-parent families as percent of all private households. This variable is available from Census 1996 and 2001, however, it is not possible to derive this variable from surveys at this time since construction of this variable requires use of household weights. Household weights are not released by Statistics Canada for use in the surveys, only individual's weights are available.

[6] Economic Conditions: long-term unemployment rate / short-term unemployment rate. The long-term unemployment rate is computed as percent of people in labour force aged 15 and older who did not have a job at any time during the current or previous year. The long-term unemployment rate is available from Census 1996 and Census 2001 but it is not available for 2003 dataset. The short-term unemployment rate, which is computed as percent of unemployed people, is available for all years of the analysis at PHU level. However, use of long-term unemployment rate instead of unemployment rate significantly improves the regression model. Therefore, the long-term unemployment rate is used for the analysis of 1999 and 2002 PHU budget per capita variation and short-term unemployment rate is used for the analysis of 2004 PHU budget per capita.

[7] Youth: percent of population younger than 15 years old. This variable can be taken from Census 1996 and 2001 and can be derived from master file of CCHS 2.1 for 2003. However, the estimates of population less than 15 years of age in 2003 might be unreliable due to the fact that CCHS 2.1 collects data only on individuals older than 12 years old.

[8] Cost of living: average dwelling value in PHU. This variable is taken from Census 1996 and 2001. Since this is Census variable, average dwelling value is not available for 2003 year. However, it was computed using 1996 and 2001 average prices of the houses by applying annual growth rates. For the preliminary analysis public health care wage index was used as a measure of cost of living. It was constructed using average salaries of full-time public health nurses and public health inspectors. Even though wage index performed slightly better in the regression model, wage index was substituted for the average housing value since it is easier to interpret the results using average dwelling value. As well, the wage index might be unreliable due to its heterogeneity.

[9] Governance Model: type of board of health in PHU. There are twenty six Single and Multi-Municipal Autonomous Boards, ten Regional Councils and Single-Tier Municipalities and one City of Toronto Health Unit. When added to the model, this variable proved to be insignificant and didn't improve the model at all. Therefore type of board of health is not included into the present analysis.

[10] Public health inspection sites: total number of food premises in PHU and total number of high-risk food premises in PHU. Number of permanent and seasonal premises is available for 1999, 2001 and 2003. We experimented with including all of the above variables one by one into the regression model. However, none of them are significant in the model. Moreover, inclusion of these variables actually reduces adjusted R^2 in all four cases and makes the problem of collinearity even worse. Therefore indicators of public health data are excluded from the further analysis.

Appendix 2. Correspondence of PHU Acronyms and PHU Names	
PHU Acronym	**PHU Name**
Kent_Cht	Kent-Chatham Public Health Unit
King_Fr	Kingston-Frontenac-Lennox and Addington Public Health Unit
Lambt	Lambton Public Health Unit
Leeds_Gren	Leeds-Grenville-Lanark Public Health Unit
Mid_Lond	Middlesex-London Public Health Unit
Musk_PS	Muskoka-Parry Sound Public Health Unit
Niag	Niagara Public Health Unit
North_Bay	North Bay Public Health Unit
Northwest	Northwestern Public Health Unit
Algoma	Algoma Public Health Unit
Brant	Brant Public Health Unit
Durham	Durham Public Health Unit
Elgin_ST	Elgin-St Thomas Public Health Unit
Bruce_Grey	Bruce-Grey-Owen Sound Public Health Unit
Hald_Norf	Haldimand-Norfolk Public Health Unit
Halib	Haliburton-Kawartha-Pine Ridge Public Health Unit
Halton	Halton Public Health Unit
Ham	Hamilton Public Health Unit
Hast_PE	Hastings and Prince Edward Public Health Unit
Huron	Huron Public Health Unit
Simcoe	Simcoe Public Health Unit
Sudbury	Sudbury Public Health Unit
Thunder_B	Thunder Bay Public Health Unit
Timisk	Timiskaming Public Health Unit
Wat	Waterloo Public Health Unit
Well_Duff	Wellington-Dufferin-Guelph Public Health Unit
Wind_Ess	Windsor-Essex Public Health Unit
York	York Public Health Unit
Toronto	Toronto Public Health Unit
Ottawa	Ottawa Public Health Unit
Oxford	Oxford Public Health Unit
Peel	Peel Public Health Unit
Perth	Perth Public Health Unit
Peterb	Peterborough Public Health Unit
Porcup	Porcupine Public Health Unit
Renfr	Renfrew Public Health Unit
East_Ont	Eastern Ontario Public Health Unit

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