CHANGING HEALTHCARE CAPITAL-TO-LABOR RATIOS: EVIDENCE AND IMPLICATIONS FOR BENDING THE COST CURVE IN CANADA AND BEYOND

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Changing Healthcare Capital-To-Labor Ratios: Evidence and Implications for Bending the Cost Curve in Canada and Beyond[1]

Abstract

Healthcare capital-to-labor ratios are examined for the 10 provincial single-payer health care plans across Canada. The data show an increasing trend - particularly during the period 1997-2009 during which the ratio as much as doubled from 3% to 6%. Multivariate analyses indicate that every percentage point uptick in the rate of increase in this ratio is associated with an uptick in the rate of increase of real per capita provincial government healthcare expenditures by approximately \$31 (p < 0.01). While the magnitude of this relationship is not large, it is still substantial enough to warrant notice: every percentage point decrease in the upward trend of the capital-to-labor ratio might be associated with a one percentage point decrease in the upward trend of per capita government healthcare expenditures. An uptick since 1997 in the rate of increase in per capita prescription drug expenditures is also associated with a decline in the trend of increasing per capita healthcare costs. While there has been some recent evidence of a slowing in the rate of health care expenditure increase, it is still unclear whether this reflects just a pause, after which the rate of increase will return to its baseline level, or a long-term shift; therefore, it is important to continue to explore various policy avenues to affect the rate of change going forward.

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1.   Introduction:

Given recent indications of a slowdown in the growth rate of health expenditures in the West, there is a question as to whether this change is permanent or transitory (CIHI, 2013; NCHS 2013; OECD 2013).   Beyond some cost savings from increased substitution of lower-priced generic drugs for name-brand drugs as patents expire, there is still little evidence of a sustained slowing of the technology pipeline—the primary determinant of long-run cost growth; thus, some substantial growth is forecast over the next two decades (Chandra, Holmes, and Skinner, 2013; Medmarket Diligence, 2013; OECD, 2013).   Moreover, service industries, like healthcare, often have intrinsically low capabilities of substituting capital for labor and hence have a relatively low capital-to-labor ratio.   In such industries, the performance of a service traditionally requires supplier and consumer to be face-to-face rather than substituting technology as the ultimate supplier (Marris 1984).   This limitation and the strong pipeline suggest that there is still a need to further investigate the dynamics that cause healthcare expenditures to increase in order to fashion new policies to stem this growth.   A natural question arises as to whether the recent trend towards increasing capital intensity in the healthcare sector—albeit still lower than other sectors—can be associated with lower rates of expenditure growth or whether the opposite is true (Chandra, Holmes and Skinner, 2013; MacDonnell and Darzai, 2013; CIHI, 2013).   Continued high labor intensity despite the latest trend may indicate the occurrence of one of two phenomena: Either the full potential for substituting technology/capital for labor in this sector has yet to be realized or technology has been more of a cost driver that complements—rather than substitutes for—labor.

In Canada, provincial government health expenditures rose at an average annual rate of 6.2% during the period 2000-2009.   This compares to a 3.8% average annual growth rate during

the 1990s (CIHI, 2011a). Similar rates of increase have been noted in other Western countries (OECD, 2013). These trends underscore the need to better understand which factors drive these cost increases.   The Canadian Institute of Health Information (CIHI) recently produced a report on health care cost drivers within Canada, but found that the role of capital and technological change difficult to quantify (CIHI, 2011b).

This paper builds on the earlier work of Di Matteo and Di Matteo (1998) and Di Matteo (2010) to examine the determinants of Canadian provincial government health expenditures with a new focus on the capital-to-labor ratio as an important determinant not examined in this earlier work.   The study utilizes data from Statistics Canada and the Canadian Institutes for Health Information (CIHI) from 1981-2009 to examine the association between *overall*—public sector combined with private sector--healthcare capital-to-labor ratios and per capita *Provincial government* health expenditures in each of the ten Canadian provinces. The paper also discusses the policy implications of these trends and the potential for managerially bending the cost curve in the coming years. Given the dearth of data on this topic from the OECD and U.S. Bureau of Labor Statistics, the Canadian data may also be a bellwether of trends and effects elsewhere.

2.   Conceptual Model:

Capital and labor are neoclassically connected to expenditures when modelling technical efficiency either through quality/outcomes- and productivity-controlled cost minimization or output maximization subject to a budget.   A change in the ratio of capital-to-labor may very well lead to measured changes in output while holding costs constant leading to enhanced technical efficiency; however, given noted difficulties obtaining a single all-encompassing measure of output and input in a multi-product industry like healthcare, it is perhaps easier to model the dual problem—minimizing per capita expenditures while attempting to control for productivity and

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outcomes (Garber and Skinner, 2008).

In the Canadian healthcare sector, there is both inelastic demand and lagging growth in labor productivity along at least one dimension. Real sector-specific GDP per healthcare worker has fallen from 74 per cent of the all-industry average in 1987 to 52 per cent in 2006 (Sharpe, Bradley and Messinger, 2007). While this measure is primarily based on the volume of inputs rather than measuring productivity in terms of the impact of inputs on output, this input measure may be most associated with the "coat-tails effect" noted by Baumol and Bowen (1966, 1996) from growth in overall GDP per worker exogenous to the health care system (Evans, Barer, and Schneider, 2010). Even so, controlling for both this measure of input and a measure of health status/quality in an analytical model of health expenditures may combine to produce a rough control for quality-adjusted output even though it is still measured at input—rather than output—prices.[i]

Economic theory does not clearly suggest how healthcare capital-to-labor ratios should impact upon per capita expenditures. If investments in technology have primarily produced cost-saving products with controlled diffusion, then higher capital- to-labor ratios should be associated with lower rates of expenditure increase—or even decrease--controlling for other factors like prices and population aging. On the other hand, higher capital-to-labor ratios could be associated with higher expenditures in the health care sector if the capital investments have largely produced either cost-increasing technologies or cost-saving technologies that have diffused substantially more than the technologies they are replacing. While greater capacity for utilizing technology/capital could potentially ease problems associated with impending labor shortages in some parts of this sector due to an aging healthcare workforce, there is also the potential for further investments in capital/technology to lead to rapid cost increases (Okunada

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and Murthy 2002, Scitovsky 2005).

Regarding exogenous Baumol effects, theory would suggest that increases in capital intensity over time in a sector with lagging input-based productivity and inelastic demand could provide a wide possible range for such effects. This depends on whether the capital investments in healthcare are largely cost-enhancing or cost-saving in nature, respectively (Pomp and Vujic, 2008). If technological innovation has mainly led to cost-saving products, then the net effect would be small or even negative; but if innovation led mainly to technologies that expanded the number of expensive treatment options, then the Baumol effect would be further strengthened (Pomp and Vujic, 2008). Given recent increases in capital intensity in the healthcare sector, it is therefore important to measure the impact of the capital-to-labor ratio on real per-capita expenditures while controlling for these Baumol effects.

In addition to these measures, expenditures in the health care sector can be impacted by a variety of other factors either in cross-section and/or longitudinally that might be included in an ad-hoc intertemporal cost-function. First, per-capita government expenditures should be deflated to control for the overall price level. As well, the analysis should control for other correlates of cost including: expenditures on prescription drugs—a category of expenditure that does not strictly fall under capital or labor, aging of the population (Di Matteo and Di Matteo, 1998), major changes in tax revenues and overall federal transfers—largely fungible at the provincial level (Banting and Boadway, 2004), and density of physicians to adjust for supplier-induced demand (Rice and Labelle, 1989).

3. Data:

The capital-to-labor ratio is constructed from the different expenditure categories

obtained from The Canadian Institute for Health Information *National Health Expenditures Report* for the period 1981-2009 (CIHI 2011c). Capital--classically defined as the service use on the stock of long-lived assets and their associated depreciation--in these data include public and private sector acquisition expenditures for construction, machinery, health technology equipment and some software of hospitals, clinics, first-aid stations and residential care facilities. The capital expenditure figures in the CIHI data are derived from Statistics Canada's Capital Expenditures Survey and are based on full-cost or cash-basis accounting principles; further, capital expenditures are defined so as to exclude operating/material cost expenditures, most of which fall under the CIHI expenditure category of hospital expenditures (Statistics Canada. 1997-2009a; CIHI, 2012). They also exclude drug expenditures—both prescription and over-the-counter--as well as personal health supplies (e.g., oral hygiene, diabetic test strips, and incontinence products) as these all belong in their own expenditure category separate from capital. All other CIHI expenditure categories—hospitals, other institutions, physicians, other healthcare professionals, public health, administration, and other health expenditures (e.g., research)--are assumed to involve exclusively labor expenditures; however, it is possible that some of the funds directed at institutions, like hospitals, and other healthcare spending could be partially used for capital purchases. Given that only 60% of Canadian hospitals expenditures are for labor with an unknown proportion of the remainder for material costs and capital[ii], this assumption means that the capital-to-labor ratios derived from CIHI data may overestimate labor and underestimate capital expenditures (CIHI, 2013).

4. Methods and Statistical Model:

The unit of analysis is at the provincial level, since each province essentially runs its own single-payer healthcare system with some common characteristics stipulated by the Canada

Health Act.   Since private sector expenditures can and often do impact government health costs, it is prudent to include these expenditures—approximately 35% over and above provincial government health expenditures-- in any capital-to-labor ratio when analyzing the impact on provincial government expenditures (CIHI, 2011d). Therefore, an ad-hoc intertemporal cost function for the Canadian healthcare sector might be specified as follows:

$$RPCAPEX = \beta_0 + \beta_1(K/L)_{it} + \beta_2(PxDrugs)_{it} + \beta_3(\%Age019)_{it} + \beta_4(\%Age65+) + \beta_5(TotFedTr)_{it} +$$
$$\beta_6(Hlthprem)_{it} + \beta_7(SID)_{it} + \beta_8(Baumol)_{it} + \beta_9(Prod)_{it} + \beta_{10}(HS)_{it} + u_{it} + \varepsilon_{it}$$

Where:

RPCAPEX	=	real ($CDN Chained GDP deflator 2002=100) per capita annual provincial government healthcare expenditures (CIHI, 2011a; Statistics Canada. 1997-2009b)
K/L	=	annual overall capital/labor ratio on total health spending (public + private sectors) (CIHI, 1981-2009b). For this analysis, the capital-to-labor ratio incorporated public sector as well as private sector healthcare expenditures—approximately 30% of the total—since these expenditures often induce further provincial government healthcare expenditures.
PxDrugs	=	real ($CDN Chained GDP deflator 2002=100) per capita overall (public and private sector) outpatient prescription drug expenditures (CIHI, 2011c)
%Age019	=	% of population age 0-19 (Statistics Canada, 1981-2009a)
%Age65+	=	% of population age 65+ (Statistics Canada, 1981-2009a)
TotFedTr	=	real ($CDN Chained GDP deflator 2002=100) revenue per capita from *total* federal transfers to provinces (not just those related to health)[iii](Statistics Canada 1981-2009b)
HlthPrem	=	Health premium dummies for years in which health premium taxes were collected in provinces that had such taxes (yes = 1, no = 0).
SID	=	measure impacting supplier induced demand: physician density— physicians per 10,000 population (Scott's Medical Database 1981-2009)
Baumol	=	measures of Baumol effects—difference between real (chained 2002 $) GDP per worker in the overall economy and real ($CDN Chained GDP deflator 2002=100) GDP per worker in the health and social assistance sectors (Statistics Canada 1997-2009b)
Prod	=	productivity measure for health care sector: Sector-specific real ($CDN Chained GDP deflator 2002=100) GDP per worker employed in the health and social assistance sectors (Statistics Canada 1997-2009d)
HS	=	health status: Statistics Canada Functional Health Index: % of population in very good or perfect health (Statistics Canada 1997-2009c)
u_{it}	=	between-province error term
ε_{it}	=	within-province error term

The full model and various other specifications are constructed based on the years in which the productivity and quality control/outcomes variables are available from 1997-2009. To compare results over a longer time period, regression models are estimated excluding these two sets of variables both for this time period as well as for a longer period back to 1981 during which these variables are unavailable. (See Tables 2 and 3.)

Several diagnostic tests are employed to determine the proper regression model to analyze these data. Statistical tests on unit roots determined whether there is a need to construct first differences to establish stationarity and whether the variables of interest are cointegrated (Levin-Lin-Chu, 2002; Persyn and Westerlund, 2008). The Hausman test for correlation between the error term and the regressors is then employed to determine whether to use random- or fixed-effects regression models to analyze the data (Greene, 2011). Further, in order to adjust for the presence of cross-sectional heteroskedasticity and serial correlation within each panel, the Huber-White sandwich estimator of variance is employed in all regression models. (Froote, 1989; Greene, 2011).

All statistical analyses are performed using STATA v. 12 (StataCorp. 2011).

5. Results: Analysis of Trends and Summary Statistics

Insert Figure 1 here

The data in Figure 1 show that the capital-to-labor ratio in the healthcare sector has been rising with a sharp jump beginning in around 1998 after some years of decline. In 1997, the capital-to-labor ratio for healthcare nationally is just above 0.03 rising to over 0.06 nationally for 2009. An increase in the capital-to-labor ratio could be due to either an increase in capital

expenditures relative to that for labor or a decrease in total labor expenditures relative to that for capital. An examination of the CIHI data both show an upward trend since 1997 in both capital and labor, and with the exception of a lull in the mid-1990s, there has been a steady increase in both measures back to 1981 (See Fig. 2). On net, the growth in capital has outpaced the growth in labor since 1997 in a health sector that consumes over half of provincial government budgets (CIHI, 2011e).

Insert Figure 2 here

Summary statistics are contained in Table 1:

Insert Table 1 here

Real per capita provincial government expenditures vary in the provincial data between $1,236 and $4,697 increasing continuously during the period 1981 to 2009, and real per capita overall prescription drug expenditures vary between $79 to $734 during this same time period. Likewise, the CIHI capital-to-labor ratio also varies between 0.01 to 0.19 across the provinces with some noted increases since 1997 as is shown nationally in Figure 1. While the mean age of the provincial populations increase 7 years from 33 yrs. in 1981 to 40 yrs. in 2009, the mean age in the data span nearly 12 years, from 29.5 yrs. to 41.4 yrs., suggesting some variation in age structure across the provinces as confirmed by the percentage breakdown by age category (Statistics Canada. 1981-2009a). The number of physicians average 17.1 per 10,000 residents varying between 10.6 and 23.3 across the provinces since 1981. As well, total federal transfer payments per capita vary widely in the data from $443 for Ontario in 1982 to $6,297 for Newfoundland and Labrador in 2005.

For the more abbreviated time period of 1997 to 2009, GDP per worker in the health and social assistance sectors averages $47,400 and tracks substantially lower than the same metric for

the overall economy as noted by the Baumol differences. Statistics Canada's functional health measure averages 80.0% of the population reporting very good or perfect health while varying between 74.2% to 90.7% across the provinces. Functional health has no clear secular trend nationally, but has some trend downward over time in the Atlantic provinces.

5.1 Results: Multivariate Analysis

Levin-Lin-Chu unit root tests suggest that the data lack stationarity ($p > 0.05$) necessitating taking first differences upon which stationarity is better established ($p < 0.01$), and the Westerlund test confirms that the variables of interest are cointegrated after differencing ($p < 0.01$). The Hausman test shows statistically insignificant ($p > 0.05$) correlation between the error term and the regressors for the first differenced data; therefore, a random-effects model is chosen to analyze the first-differenced data.

The results of the regression analysis are contained in Tables 2 and 3 for 1997 – 2009 and 1981-2009, respectively. To test for the stability of the association between the capital-to-labor ratio with per capita healthcare expenditures, both a longer and shorter analytical timeframe and seven different model specifications are used.

Insert Tables 2 and 3 here

The results in Table 2 indicate that every percentage point uptick in the rate of increase in the capital-to-labor ratio is associated with an uptick in the rate of increase in real per capita provincial government healthcare costs by approximately $31—a figure that does not vary substantially across different model specifications. This magnitude does not change substantially when the measures for production inputs and health status (functional health) are removed. Further, this magnitude is approximately 44% larger than recorded in Table 3 when the timeframe of the analysis is increased back to 1981 at which time the outcomes and production input measures are unavailable; however, because the removal of these two variables had no

impact on the association in the shorter data series, it can be inferred that the absence of such control variables in the longer data series cannot be responsible for the lower magnitudes observed. A statistically significant ($p < 0.01$) association between real per capita prescription drug expenditures and per capita healthcare expenditures is most noted in the period 1997-2009, but not over the entire period back to 1981 (See Tables 2 and 3).   For the period 1997-2009, a dollar uptick in the rate of increase expended on prescription drugs is associated with almost a $4 decline in the rate of increase in real per capita government health expenditures. Age distribution has no statistically significant ($p < 0.05$) association with real per capita government health expenditures in either the short-term or longer-term data series. Even though there is a noted increase in physician density in many provinces since 1997, no significant association is noted between physicians per 10,000 population and per capita government health expenditures during either the most recent data series or the longer data series back to 1981 (Scott's Medical Database [CIHI], 2012). There is also a statistically significant association ($p < 0.05$) between the presence of a health premium/tax—though often not earmarked specifically for health--in a province.   Lastly, there is an uptick in the rate of change in total federal transfer payments and the rate of increase in real per capita government health expenditures ($p < 0.05$).   The hypothesized coat-tails or Baumol effects from overall increases in productivity are absent in these data.

6. Discussion:

The Canadian Institutes of Health Information (CIHI) has recently released a report entitled, *Measuring the Level and Determinants of Health System Efficiency in Canada*, which utilizes Data Envelopment Analysis (DEA) to analyze output at the health region level to determine whether the health system is operating efficiently by maximizing potential years of life lost given available funding levels (CIHI, 2012a; CIHI, 2014).   The findings are that between 12,600 and 24,500 premature deaths could be avoided if maximum output were

achieved within existing funding envelopes (CIHI, 2014). While these findings are of interest, this single- dimension output measure fails to account for inefficiencies that might be due to unrealized potential to reduce morbidity beyond those measured for reductions in mortality. Like the CIHI paper, there have been other papers that utilize production frontier envelopment methods to examine productive efficiency; however, they have focused generally on quantifying inefficiency *per se* rather than examining the impact of varying levels of capital and labor (Afonso and St. Aubyn 2006, Hollingsworth 2008).

The analysis, herein, uses non-frontier methods like Di Matteo and Di Matteo (1998) to analyze the dual problem: minimizing expenditures while attempting to control for health system productivity and health status beyond a dichotomous measure for mortality. Given that the CIHI analysis faces difficulties in both analyzing output at the level of the health region when a multitude of services are often provided across boundary lines and quantifying multiple independent outputs under a single measure, it appears preferable to work with the dual problem as proposed here.

The different model specifications in this paper measure a $31 uptick in the annual rate of increase in real per-capital provincial government health expenditures associated with every percentage point uptick in the rate of increase in the capital-to-labor ratio.   This magnitude is about 44% larger than when considering the longer time frame back to 1981. While the magnitude of the most recent association is not large, it is still substantial enough to warrant notice: every percentage point decline in the rate of increase of the capital-to-labor ratio is associated with a one percentage point decrease in the underlying upward trend in per capita provincial healthcare expenditures since 1997 (CIHI 2011e).[iv]   The use of first differences for the analytical variables also may measure incremental spending on new capital as opposed to new expenditures on the entire stock of capital some of which offsets depreciation and/or involves the cost of replacing existing capital.

There is recent anecdotal evidence from examining functional cost centers in the province of Ontario that support the findings in this analysis. This evidence suggests that increases in capital expenditures during the period 2002-2005 have been cost-increasing. Mainly in response to new federal funds specifically earmarked for health technology in 2000 and 2004, the hospital subsector experienced large increases in capital costs (8% - 10% annually from 2002-2005 vis-à-vis labor-related costs (1% - 5%) due mainly to increases in expenditures related to equipment and supplies (75% of total increase) and to increased use of inpatient drugs (remaining 25%) as potential substitutes for contact hours with health professionals.[v,vi] Yet during this time, annual increases in Ontario's per capita provincial government health expenditures approach 10% -- higher than in years immediately before and after this period (CIHI, 2011e).

Thus, the lack of a measured Baumol effect in these data is surprising particularly given evidence from OECD member countries showing a relatively strong effect (Pomp and Vujic, 2008); yet, such a result is possible if factors endogenous to the health care sector are primarily responsible for the noted expenditure increases rather than exogenous ones. This suggests that growth in health care expenditures related to increased capital intensity may be driven more by decisions internal to the health care system rather than overall economic growth. The federal-provincial accords in 2000 and 2004 that specifically designated funds for the acquisition of health care technology are examples of such a dynamic. Further, the noted expenditure increase associated with capital may be at the intensive margin—widespread diffusion of any new technologies regardless of whether technology is cost-saving or cost-increasing per unit employed; hence, the expenditure increase measured in the data may be more associated with the capital-to-labor ratio rather than Baumol effects. If so, this would explain the lack of such an effect as theorized by Pomp and Vujic (2008).

While new roles for partial physician substitutes, like nurse practitioners and pharmacists are just being legislated in Canada, there are many other new innovations in the use of personnel

and even technology that have produced phenomenal cost savings in the developing world (MacDonnell and Darzai, 2013).   Thus, capital expenditures for recent generations of diagnostic imaging technologies that dominated the data in this study-- like CT and MRI machines--that spurred on new expensive medical interventions may not be reflective of the impact on costs from a new generation of medical innovation centered around smartphones, other mobile devices, and information technology.

On the matter of out-patient prescription drugs, which has generated much controversy over their impact on total costs, these results indicate that these added expenditures have led to decreases in the rate of growth of total provincial government health expenditures in recent years. (Cutler, 2004; Lichtenberg, 2007; Okunada and Murthy, 2002; Scitovsky 2005).   Though this finding is not as consistent as with capital-to-labor ratios when examined over the entire period of this study, it is important both because of the observed effect size and because expenditures on prescription drugs have risen rapidly since 1997. While expenditures on drugs occur mainly outside of direct provincial government control in the private sector, these results shows that there are important downstream effects on government healthcare budgets. Again, this is just an average tendency since there are individual pharmaceutical products that are, on net, cost increasing (Cutler 2004, Lichtenberg 2007).   While there is supportive evidence of net cost savings with regard to Statins and other cardiovascular drugs that show an associated decrease in the number of contact hours with health professionals and hospitalizations, there have also been a number of effective, but cost-increasing drug combinations for treating Acquired Immunity Deficiency Syndrome and Hepatitis C (Brown and Garber, 1998; Grover et al. 2003; Havlir, Marscher and Hirsch et al., 1998; Davis, Esteban-Mur and Rustgi et al. 1998) . Not only are such drugs often covered by provincial drug programs, but they also keep such expensive-to-treat patients alive for significantly longer periods.

The lack of a large measured impact from total federal transfers on overall provincial

health expenditures may indicate one of two phenomena: Either the provinces pull back expenditures in other areas of the health care system when funds are directed by federal mandates to certain priority healthcare areas or that changes in federal transfers to sectors other than health do not impact provincial decisions about how much to spend on the health portfolio. This observed effect suggests that provinces have largely maintained a certain trajectory of health spending regardless of how much money—albeit largely fungible--flows from the federal government.

7. Limitations:

There are also important limitations to this analysis. First, this paper does not address issues regarding allocative efficiency. Technical efficiency issues aside, there remains the unanswered question as to whether each marginal dollar expended on health care exceeds the opportunity cost of other goods and services that could be alternatively provided.   Second, the CIHI data used to define "capital" in this study probably underestimated capital expenditures and increasingly so after 2000 when there was an influx of imaging and other technologies in hospitals due to new federal funding accords for health care technology. On the other hand, the CIHI data may have included expenditures under capital beyond the standard definition of service use on the stock of long-lived assets and associated depreciation.   Third, the CIHI data overestimated labor expenditures particularly due to placing the category of hospital expenditures entirely under labor. Consequently, the association between the capital-to-labor ratio and per capita expenditures may be upwardly biased since the CIHI ratio probably fails to capture the full growth in capital intensity evident during the period 1997-2009; therefore, the magnitude of the results herein should be considered cautiously. Fourth, the analysis did not include such health behavior data known to impact upon healthcare expenditures like smoking and obesity, the latter of which has risen to epidemic levels in recent years. Fifth, the chained GDP deflator used in these data cannot be expected to fully deflate prices in the health care

sector which have increased at a rate differing from economy-wide averages, and it cannot be assumed that capital and labor in the health care sector have experienced the same level of price inflation during the period of this study. Sixth, it is assumed that first differencing of the capital-to-labor ratio controls for all vintage effects in capital and depreciation of the capital stock; however, some replacement of older equipment may result in a residual uptick in the rate of increase in this ratio particularly in the area of diagnostic imaging equipment. Finally, and possibly most importantly, this analysis, though it attempted to do so, probably does not control adequately for outcomes and productivity in the health sector given the difficulty of fully measuring such values in the national accounts for a multi-product sector like health (Evans, Barer, and Schneider, 2010). Nevertheless, there may be a need to further investigate this issue at the institutional level or at the level of specific diseases—where technical efficiency is most commonly measured—given that the productivity measures provided in this analysis are all rising during this period of increasing capital-to-labor ratios.

9. Conclusion and Policy Recommendation:

Although this analysis does not provide conclusive proof of how to achieve a cost-minimizing equilibrium, it does suggest that an economic agent--like a hospital administrator, the government, or even a health care provider—may consider encouraging the use of medical interventions which are less rather than more capital intensive; however, this criterion should only be considered when there is good evidence that comparison interventions are of similar effectiveness and quality. There are a large number of health technology assessment agencies around the world affiliated with the International Network of Agencies for Health Technology Assessment (INAHTA) that report on the quality of various healthcare interventions that may help in such decision-making. From a managerial perspective, a potential improvement in technical efficiency might be achieved through a system of gain-sharing with providers who

selectively decommission expensive, ineffective technologies, limit the use of discretionary technologies, and/or employ cost-saving technologies (Gaynor, Rebitzer and Taylor, 2004). This direction has been taken by primary care trusts in Great Britain and accountable care organizations in the United States. Such a criterion would be equivalent to the Kaldor-Hicks criterion in the realm of allocative efficiency that posits a potential Pareto improvement by financially compensating individuals that might lose utility through the process of reallocating resources. In this case, compensating labor for employing added cost-saving measures could produce potential improvements in technical efficiency. While there has been some recent evidence of a slowing in the rate of health care expenditure increase, it is important to continue to explore policy avenues like gain-sharing to continue this trend going forward.

In the end, determining the technically efficient ratio of capital-to-labor may be a necessary, but insufficient, condition for achieving overall efficiency in the health care system. Also necessary to consider is how best to control demand- and supply-side moral hazard and other information asymmetries largely due to third-party coverage. This leaves producers of technologies (e.g., pharma), users of technology (physicians and other health professionals) and consumers to be less cost-conscious than perhaps with other services. Perhaps current reforms in reimbursement, like risk-adjusted capitation of physician services or bundled payments for episodes of care, may help align overall payment incentives with the goal of containing costs. Combined with determining the technically efficient ratio of labor and capital, these reforms may help to make theorized cost-efficiencies an ultimate reality.

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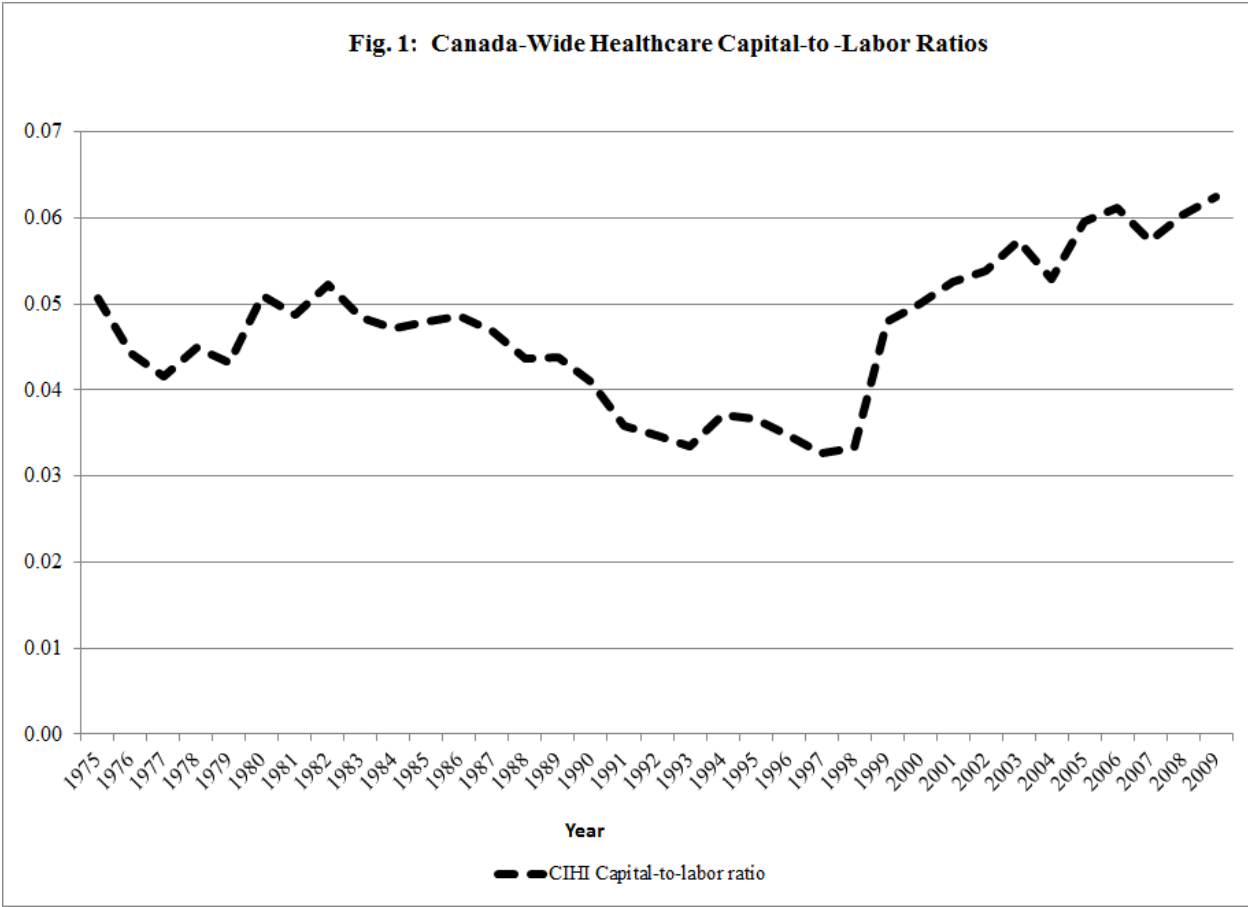
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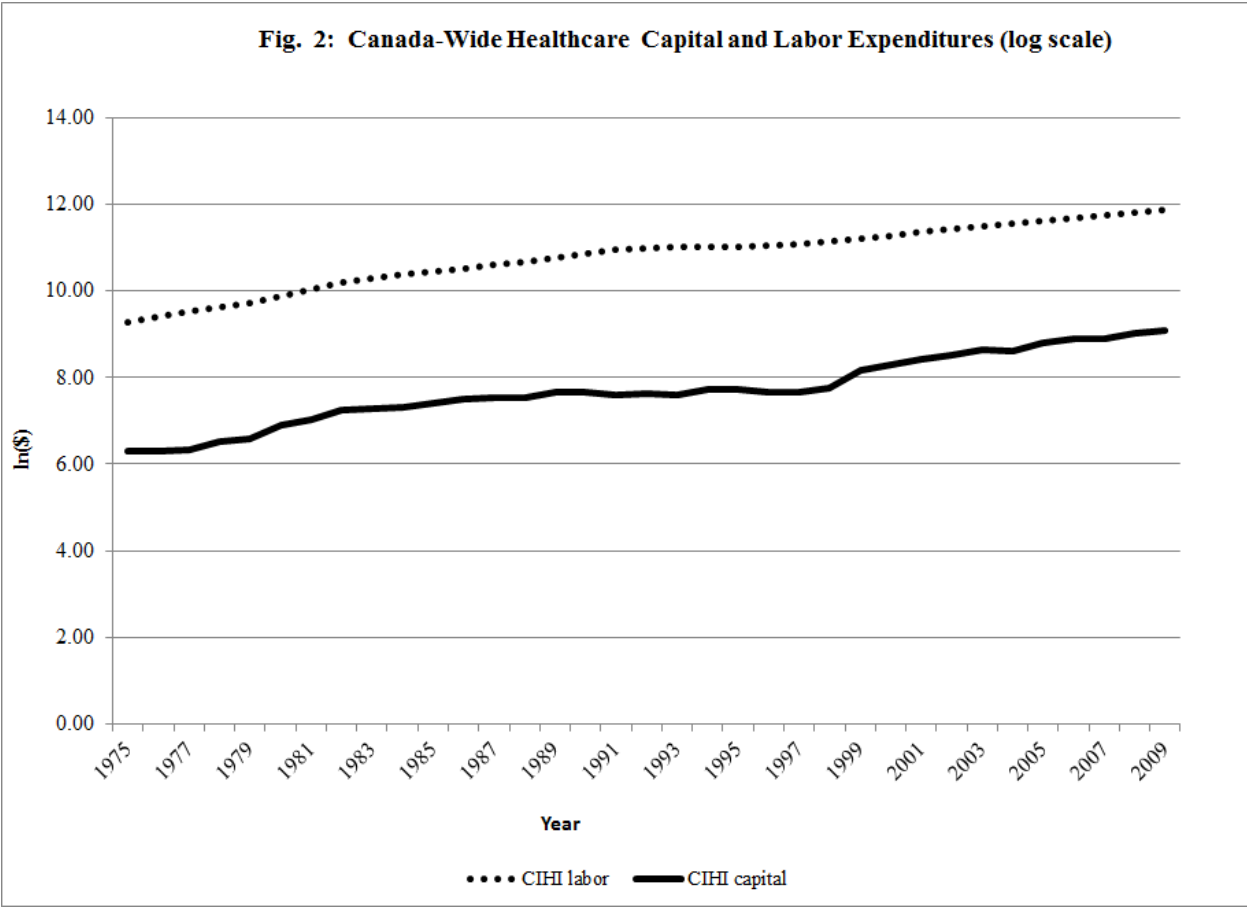
11. Explanatory Notes:

[i]   Given Canada's largely publicly--as opposed to largely privately--financed health care system, it is conceptually difficult to determine output prices; thus controlling for inputs simultaneously with health status may control for at intermediate outputs and at least partially for final outputs in the Canadian healthcare system.

[ii]   While there is no exact breakdown for Canadian hospitals, data from American hospitals report 51% of expenditures for labor with 42% for operating costs and materials, and another 7% for capital (http://www.mnhospitals.org/mn-hospitals/hospital-financing-101).

[iii]   Total federal transfers are included rather than those specific to health given that provincial governments often adjust their own allotments given to certain portfolios based on the availability of overall federal funding; that is, federal transfers to the provincial government are considered fully fungible except in rare circumstances when funds are designated specifically for a particular purpose (Banting and Boadway, 2004) . Therefore, it is not inconceivable that health spending by the provinces is impacted by the availability of federal transfers to help defray the cost of, for example, transportation or energy projects.

[iv]   5.0% of a nationwide 2009 average per capita provincial government health expenditure of $3,500 equals $175. The regression results indicate that the impact of a 1 percentage point increase in the capital-to-labor ratio is approximately $31 which is between $1/5^{th}$ and $1/6^{th}$ of this total.

[v]   Ontario Health Reporting Standards (OHRS) dataset.

[vi]   Other sectors are also important such as out-of-hospital prescription drugs and physician services.   The former is difficult to gauge given large sectors of the population having private drug coverage. Since physician offices are private businesses, breakdowns in their expenditures are generally not reported.

12. Figures:

Fig. 1: Canada-Wide Healthcare Capital-to-Labor Ratios

Source: CIHI NHET report 1975-2011 Table A.3.1.1 Total Health Expenditure, by Use of Funds, Canada, 1975 to 2011—Current Dollars.

Fig. 2: Canada-Wide Healthcare Capital and Labor Expenditures (log scale)

Source: CIHI NHET report 1975-2011 Table A.3.1.1 Total Health Expenditure, by Use of Funds, Canada, 1975 to 2011—Current Dollars.

13. Tables:

Table 1:
Summary Statistics
(Over 10 Provinces)
(1997-2009 in black) (1981-2009 in gray)

Variable	Mean	Standard Deviation	Minimum	Maximum
RPCAPEX	$2,613.23	$614.38	$1,672.17	$4,696.86
	$2,181.81	$595.27	$1,236.05	$4,696.86
K/L	0.05	0.02	0.02	0.11
	0.05	0.02	0.01	0.19
PxDrugs	$455.91	$114.59	$236.16	$734.33
	$320.14	$154.12	$79.22	$734.33
Mean age	38.27 yrs	1.54 yrs	34.40 yrs	41.40 yrs
	36.16 yrs	2.45 yrs	29.50 yrs	41.40 yrs
%Age019	25.3%	2.21%	21.29%	30.46%
	27.96%	3.47%	21.29%	40.38%
%Age2064	61.44%	2.08%	55.52%	64.55%
	60.04%	2.70%	52.12%	64.55%
%Age65+	13.21%	1.42%	9.56%	15.76%
	12.00%	1.88%	6.95%	15.76%
TotFedTr	$1,974.70	$1,121.52	$443.09	$6,297.02
	$1,855.51	$974.17	$443.09	$6,297.02
SID	18.20	2.41	12.10	23.30
	17.10	2.66	10.60	23.30
Baumol	$35,481.21	$9,242.81	$23,241.33	$62,869.02
	N/A	N/A	N/A	N/A
Prod	$47,362.11	$6,736.10	$36,388.78	$67,480.99
	N/A	N/A	N/A	N/A
HS	80.01%	3.37%	74.20%	90.65%
	N/A	N/A	N/A	N/A

Note: N/A denotes data not available over this time frame.

Table 2:
Regression Analysis of Per Capita Provincial Government Expenditures (1997-2009)
First Differences
(random effects model with outcome and productivity control variables, in black
(random effects model without outcome and production control variables, in gray

Dep. Variable: *RPCAPEX*	Model #1 (SE)	Model #2 (SE)	Model #3 (SE)	Model #4 (SE)	Model #5 (SE)	Model #6 (SE)	Model #7 (SE)
K/L	$31.14** (3.40) $31.83** (3.05)	$30.92** (3.58) $32.18** (3.63)	$30.87** (3.73) $32.27** (3.96)	$33.33** (4.26) $34.32** (4.80)	$34.08** (4.50) $34.90** (5.40)	$32.23** (5.28) $33.18** (5.89)	$31.87** (6,22) $34.50** (7.45)
PxDrugs	-$3.77** (0.95) -$3.78** (0.94)	-$3.77** (0.95) -$3.67** (0.96)	-$3.78** (0.91) -$3.69** (0.92)	-$3.57** (0.84) -$3.55** (0.86)	-$3.67** (0.87) -$3.67** (0.88)	-$3.69** (0.87) -$3.70** (0.88)	-- -- -- --
%Age019	-$33.51 (58.35) -$43.28 (49.59)	-$35.21 (62.98) $16.49 (50.58)	-$35.36 (63.18) $2.94* (47.34)	-- -- -- --	-- -- -- --	-- -- -- --	-- -- -- --
%Age65+	$116.15 (89.13) $106.65 (68.53)	$114.38 (81.95) $121.86* (58.77)	$115.59 (82.02) $117.75* (57.36)	-- -- -- --	-- -- -- --	-- -- -- --	-- -- -- --
TotFedTr	-$0.017* (0.008) -$0.017* (0.008)	-$0.016** (0.006) -$0.017* (0.008)	-$0.016** (0.006) -$0.017* (0.007)	-$0.017** (0.006) -$0.017** (0.006)	-$0.017** (0.006) -$0.018** (0.006)	-- -- -- --	-- -- -- --
SID	$3.15 (28.28) $2.32 (28.57)	$3.06 (27.86) -$5.90 (27.99)	-- -- -- --	-- -- -- --	-- -- -- --	-- -- -- --	-- -- -- --
HlthPrem	$146.00* (70.88) $146.28* (72.11)	$146.20* (70.95) $161.46* (74.20)	$145.45* (72.67) $158.94* (74.04)	$151.82* (85.04) $161.77* (76.84)	-- -- -- --	-- -- -- --	-- -- -- --
Baumol	-$0.001 (0.007) -$0.0002 (0.007)	-- -- -- --	-- -- -- --	-- -- -- --)	-- -- -- --	-- -- -- --	-- -- -- --
Prod	$0.004 (0.004) -- --	$0.003 (0.006) -- --	$0.003 (0.006) -- --	$0.002 (0.007) -- --	$0.001 (0.006) -- --	$0.002 (0.006) -- --	$0.007 (0.008) -- --
HS	-$0.54 (5.55) -- --	-$0.76 (5.88) -- --	-$0.75 (5.83) -- --	$1.48 (4.71) -- --	$0.21 (5.55) -- --	$0.50 (5.68) -- --	$7.86 (5.03) -- --
Overall R^2 adjusted	0.57** 0.57**	0.57** 0.57**	0.57** 0.57**	0.56** 0.55**	0.54** 0.54**	0.53** 0.53**	0.14** 0.12**

* $p < 0.05$ **$p < 0.01$

Table 3:
Regression Analysis of Per Capita Provincial Government Expenditures (1981-2009)
First Differences

Dep. Variable: *RPCAPEX*	Model #1 (SE)	Model #2 (SE)	Model #3 (SE)	Model #4 (SE)	Model #5 (SE)	Model #6 (SE)	Model #7 (SE)
K/L	N/A	$21.66** (7.50)	$21.67** (7.49)	$22.51** (6.96)	$22.94** (7.35)	$22.85** (7.28)	$22.57** (7.50)
PxDrugs	N/A	-$1.14 (0.63)	-$1.19* (0.61)	-$1.04 (0.68)	-$1.09 (0.72)	-$1.10 (0.72)	--
%Age019	N/A	$15.74 (47.66)	$6.14 (47.74)	--	--	--	
%Age65+	N/A	$112.56 (101.04)	$129.99 (113.22)	--	--	--	
TotFedTr	N/A	-$0.004 (0.01)	-$0.005 (0.01)	-$0.002 (0.01)	-$0.003 (0.01)	--	--
SID	N/A	$30.60 (19.22)	--	--	--	--	--
HlthPrem	N/A	$165.43* (84.78)	$162.75* (81.58)	$165.82 (88.53)	--	--	--
Baumol	N/A	--	--	--	--	--	--
Prod	N/A	N/A	N/A	N/A	N/A	N/A	N/A
HS	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Overall R^2 adjusted	N/A	0.17**	0.16**	0.14**	0.13**	0.13**	0.08**

   * $p < 0.05$ **$p < 0.01$
Note: N/A denotes data not available over this time frame.
Note2: Model #1 cannot be replicated for the time frame 1981-2009 due to unavailability of data for Baumol effects for all of the years during this time period.