Health Care Expenditures in OECD Countries, Identifying the Cost of Technology

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This study explores determinants of health care expenditures, providing empirical evidence for the occurrence of both convergence as well as divergence of health care spending. Employing a panel of per capita health care expenditure data from thirteen OECD countries and quantity of MRI systems as a proxy for technology acquisition, we find that a substantial amount of the variation in level health expenditures can be explained. The empirical findings are consistent with previous postulations that technology is a statistically significant driver of health expenditures, though the evidence suggests that technology has much less of an impact on health expenditures than previously hypothesized. Further evidence indicates there is a stable relationship between technology acquisition and expenditures over the period of this study. Additionally, inclusion of the technology variable corrects missing variable bias, a problem reported in health expenditure studies. Insights from these findings also provide relevant information on the financial effects of various types of policy adoption and technology investment. Specifically we observe that integrated (public) health systems lend to lower health expenditures, while health expenditures increase when gate keeping and public reimbursement systems are initiated.

INTRODUCTION

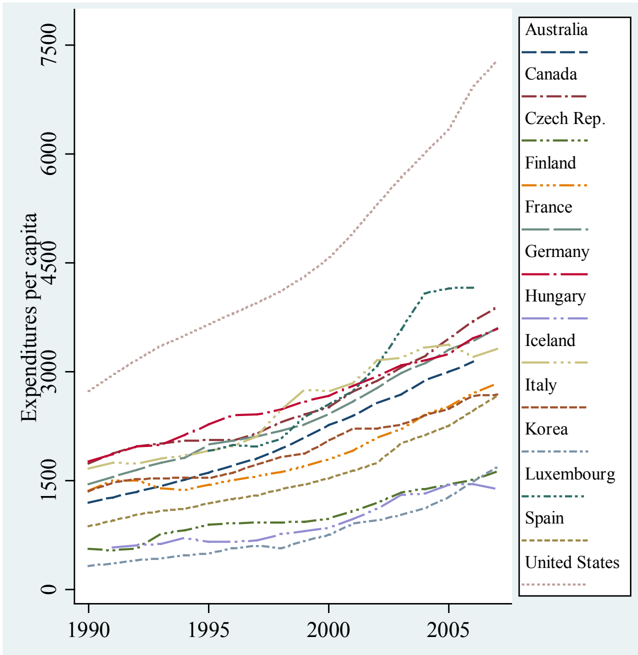
Explaining growth in healthcare expenditures has been a principal source of inquiry for academics and policy researchers. Since Newhouse's (1977) notable work on health care expenditures of 13 OECD countries, there has been an abundance of literature on the topic. For example, a PubMed search for "health expenditures" produces over 16,000 related matches. However, there still exists a paucity of empirical evidence examining the direct impact of technology on health expenditures. Alas, most of the literature addresses the impact of technology as the unexplained portion of investigation.

The purpose of this investigation is to determine what factors are driving convergence and divergence of global health care expenditures. Specifically, we examine how technology relates to factors influencing health care expenditures. From these aims, our research also provides an opportunity to investigate effects of cost containment and remuneration schemes influence health expenditures.

Visual evidence of per capita health expenditure convergence and divergence can be seen in figure 1. Clearly there are obvious upward deviations from the sample, such as the United States and Luxembourg who is seen as converging on the US from 2001 to 2003. Countries with per capita spending less than the United States appear to be converging in formations of three different expenditure groups. Composing the first group; Canada, France, Germany, Iceland, and Australia represent the nations with greater per capita spending, excluding the United States and Luxembourg. The second group Finland, Italy, and Spain represent a small group with an approximated level of per capita health expenditures. The third group;

Korea, Czech Republic, and Hungary can be seen at the bottom of the figures, as they have the lowest per capita health expenditures of the sample. However, these lowest per capita spenders of health care are increasing expenditures at the greatest rate, i.e. their rate of expenditure growth is surpassing the sample, indicating convergence with other sample nations. Not limited to these three nations or Luxembourg, nations such as Spain, Canada and others are increasing expenditures as fast, if not faster than the United States! In addition to this visual evidence, a number of papers report evidence of the convergence and divergence phenomenon (Hitiris, 1997; Hitiris & Nixon, 2001).

FIGURE 1
HEALTH CARE EXPENDITURES, 1990-2007



Source: OECD Health Data 2009

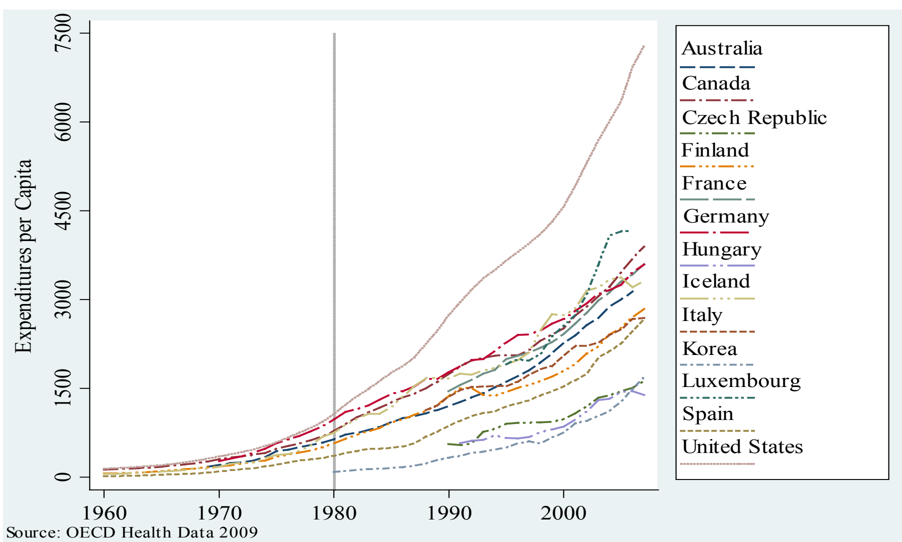
In this paper, we empirically examine magnetic resonance imaging (MRI) as a proxy for national technology procurement in a longitudinal setting, exploring the influence of procurement on convergence and divergence. Within this study the analysis will pursue four questions of interest: (1) Does the acquisition of MRI equipment serve as a proxy for technology investment? (2) What is the impact of technology? (3) What role do health system policies examined within this study play? and (4) What differentials exist between level and rate analysis?

Examining OECD countries from 1990 thru 2007, this paper uniquely contributes to the knowledge base by demonstrating that MRI is an appropriate proxy for technology. However, the empirical results reveal that technology is not as large of a contributor of health expenditures as is income. Rather it appears as if technology has an offsetting influence on expenditures where increasing and decreasing effects cancel out. Despite technology's canceling out effect, this paper documents long run increasing expenditures that tend to increase at a decreasing rate for developed nations. Decreasing rates of expenditure provide evidence of effective cost control policy. Investigation of converging and diverging influences of expenditure reveals cyclical patterns of technology, cost control advantage of public integrated systems, and expenditure effects of population aging.

EXTANT LITERATURE

Measuring the contribution of technology to healthcare expenditure has historically not been a simple task. Of the studies addressing technological influence on health expenditures, a vast majority simply attribute most if not all of a model's residual as technology costs instead of directly estimating the impact of technology. Newhouse (1992), who is consistently cited in the literature, postulates that about 65^{+} percent of health expenditure residual is attributable to technology. Employing a similar methodology, Peden and Freeland (1995, 1998), report that approximately 40-60 percent of their unexplained expenditures variation is attributable to technology. However, such speculation creates a potential for bias as other factors may not be accounted for. Barros (1998) reports of such misspecification/missing variable bias in examination of OECD health expenditures, while the reported bias maybe exclusive to technology, we do not know if other factors are not being accounted for. In addition, another potential source of bias is the time period employed when attributing technology as the source of expenditure residual variance. Referring to figure 2, we can identify that much of relevant, "concerning" variation in health expenditures is occurring after 1980, with pre-1980 expenditures exhibiting lower variance. If we assume technology is a growing source of expenditure variation, the amount of model variance explained by other factors should be decreasing, but this is not observed in the literature. Barros (1998) observes that the amount of unexplained residual is about 30 percent, less than half of what Newhouse reports in 1992. It is possible that the process of accrediting residual variance to technology could either understate or overstate the influence of technology on health expenditures. Prudence demands a direct estimation approach as the ascribing residual variance gives rise to inaccuracy.

FIGURE 2
HEALTH CARE EXPENDITURES, 1960-2007



Prior Methods of Cost Estimation

Investigations exploring the effect of technology with respect to international expenditures employ one of two basic methods, either case studies or proxy variables. While case studies can provide valuable information on specific costs, they tend to be limited in scope and lack qualities allowing for generalization. Studies using proxy variables of technology on the other hand can allow for generalization, but are less common as finding a meaningful substitute is difficult. Okunade and Murthy (2002) use research and development (RD) expenditures, both public and private, as a proxy for technological change in healthcare. Employing cointegration testing, Okunade and Murthy conclude that technology is well proxied by RD and that technology is a significant contributor to expenditure variance.

The author challenges the logical validity of employing research and development as a proxy, as there are a number of obvious problems. While RD could be a good predictor of future expenditure, in practice, RD is not adjusted for the delay in time between expenditure on RD and expenditure in health technology. A far more plausible view of RD is as an investment targeting expectation of future consumptions, tied to the state of the economy. The immediate effect of reducing RD brings about a reduction in the direct expense of RD, yet the current state of consumption of currently available goods and services would incur little to no impact. Consider the investor having to reduce RD cash out flows, assuming like probabilities of success and present values, RD reduction is more likely to affect projects requiring longer periods of capital outlay than those projects nearing the end development. Likewise, an increase in RD spending today would not result in an abundance of available technologies today, rather there would be an increase in products available in the future. Thus changes in RD have delayed, rather than immediate effects. Given the delayed effect of RD, the fundamental underpinning of employing RD as a proxy for technology rests in the selection of the applied lag structure. Selecting a lag could be challenging as various technologies progress through RD and trials at different rates. Thus an aggregate use of RD would approximate an average of numerous individual projects of varying duration, further influenced by changes and advances in research. The RD approach also fails to account for rates of technology diffusion that occur with relative access and adoption. Specifically, countries may invest in RD in varying ways and quantities. However, access to technology goods in the world market may vary and thus hinder adoption and, or increase apprehensions that may arise with new untried technology.

A different approach to direct estimation of technology effects on health expenditures by Di Matteo (2005) employs a time variable. Comparing country specific differences between Canada and the U.S., Di Matteo concludes technology change accounts for 62.3 percent of U.S. and 64.2 percent of Canadian of gross health expenditures.

This type of approach lacks plausibility and suffers from the same problems of misspecification discussed earlier. Employing an index to control for time effects is considered to be a good practice, however it would be a poor proxy of technology as unrelated trends, linear and non-linear will be captured in such a process; i.e. technology will not be exclusive within the time variable, thus overstating the impact of technology. A lone finding of correlation and supposition should be considered as falling short. It is important to note that Di Mateo also points to this potential problem. This further underscores the need for a more appropriate proxy of technology.

As the challenge to a study employing a technological component lies in finding the appropriate measure, the previous studies have been unsuccessful in providing content validity. Three sources of support for MRI acquisition as a proxy of technology are: (1) a discussion of the technology's background versus substitute technologies, (2) related findings in the extant literature and (3) statistical testing involving unit root and cointegration results which provide evidence of a long-run stable relationship between per capita health care expenditures and MRI acquirement over the period of the study, this information is reported in the appendix. Additional testing in the appendix demonstrates furthered evidence correlation and rules out missing variable bias.

Diffusion of MRI Technology

MRI technology first became commercially available in 1980 for the first time. However, despite known superiorities, adoption of the MRI technology was slower than that of competing technologies due to greater costs. Bell (1996) reports adoption rates of more than 2:1 for computed tomography CT versus MRI during the first five years of MRI availability, attributing cost differentials between the technologies as the cause of increased CT adoption. During the five year period, Bell reports global "street prices" of MRI technology converge from 1983-84 forward, signifying equal access to MRI technology on the basis of cost as the price is relatively the same across nations, as nations producing the technology likely enjoyed lower pricing. As access to MRI became relatively equal among nations, adopters of relatively inferior technologies are relatively price sensitive and thus budget constraints likely limit all technology consumption.

A small body of literature investigates MRI on an international level with respect to income or expenditure. Rublee (1989, 1994) reports the largest variation in technology diffusion amongst the U.S., Canada, and Germany is in MRI technologies. Lázaro and Fitch (1995) observe 1990 cross-sectional health care expenditures of 24 OECD countries and report significant correlations with many technologies including MRI. Lázaro and Fitch also note MRI as having the lowest correlation of (.28) versus CT (1.23) and other technologies with income (GDP). A second study by Slade and Anderson (2001) examine adoption/diffusion of five types of technologies, reporting diffusion of MRI is significantly related to income (proxy by GDP) and reimbursement conditions. Slade and Anderson further note adoption of new technology is typically seen in wealthier nations, with a five to ten year period of delay in diffusion of technologies to other nations, however they do not attempt to explain expenditures with technology. Anderson, Reinhardt, Hussey, and Petrosyan (2003) note high and low consumers of MRI in relation to expenditures of 28 OECD countries using descriptive statistics, however the values they report in study differ from the values employed in this study. "OECD indicators 2003, Volume 2001" reports values from the Anderson et al. study, noting underestimation of data that seem to have been updated afterwards. Baker & Wheeler (1998) examine a cross-sectional sample through 1994-1995, finding managed care influences MRI adoption in the U.S., suggesting that diffusion of technology is related to cost containment strategies, similar to Slade and Anderson (2001). Additionally, Baker et al. (2003) examine the diffusion of five major technologies and U.S. health expenditures, including MRI, reporting an association between regional technology availability and regional health spending. Hence emphasizing the importance of controlling for system factors such as gate keeping policies, as well as, illustrating how adoption/diffusion of technology can vary, strengthening the argument for a direct variable approach.

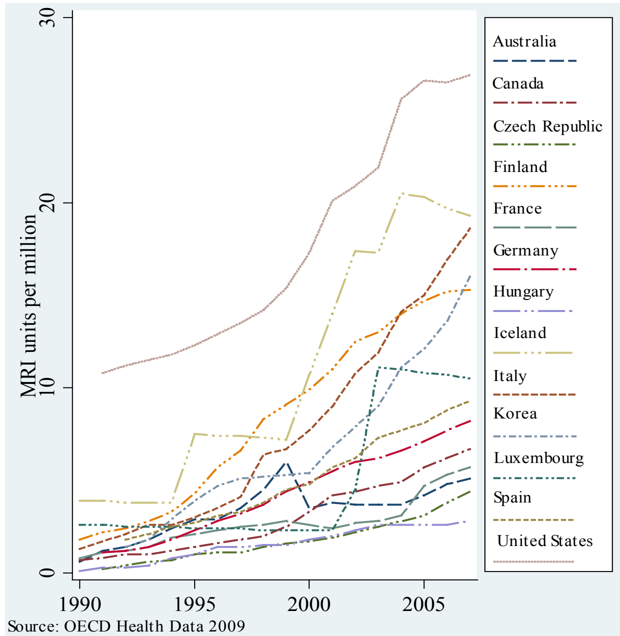
Advances in MRI Technology

Newhouse (1992) points to technology as a major driver of health care expenditures attributable to rapid technological change. This position taken by Newhouse suggests that it is important for researchers to incorporate a proxy for technology that is constantly changing, rather than remaining static. As a continually evolving technology, MRI is known for possessing advantages over competing technologies (Bell, 1996; Chalela et al., 2007). Initially available in .1-.3 T magnet strength, imaging systems are now available as strong as 9.4 T for human use, producing faster and more accurate imaging - MRI are measured in terms of T, where T stands for tesla, an international system unit of measurement for magnetic fields. Since initial availability, consumption of newer and stronger technology has continued at growing costs. As the useful life of a MRI system typically ranges from 5 to 7 years, reinvestment will likely lead to the purchase of more costly frontline technology (Bell, 1996; Fletcher, Clark, Sutton, Wellings, & Garas, 1999). The assumption of reinvestment is predicated on generally growing quantities of systems, and if reinvestment should not be occurring, system numbers should diminish. Therefore, changes in MRI acquisition capture each nation's changing preferences for technology.

Evidence in the extant literature suggests acquisition of MRI technology can be a good proxy of willingness and ability to invest in technology, while having the lowest correlation with income of available technologies, and therefore MRI should be good proxy of technology as a driver of health expenditures. This type of investment pattern may indicate a changing preference for diagnosis via technology versus physical examination and, or a greater preference for specialized care proportional to primary care.

As noted, the prices of MRI technology converge from 1983 forward, thus there is equal access to the technology in terms of expenditure. Differing from a function of targeting expectation of future consumptions, tied to the state of the economy and is not likely to over state the effect of technology by capturing extraneous effects.

FIGURE 3
MAGNETIC RESONANCE IMAGING UNITS, 1990-2007



DATA

The data and all variables are from the OECD Health Data 2009 statistics and indicators database (OECD, 2009). This source of data is used as it is employed in the majority of health expenditure studies. The data are a longitudinal panel spanning from 1990 to 2007, a total of 18 years. After removal of missing data, the final data set employed for this study consists of 13 countries- Australia, Canada, Czech Republic, Finland, France, Germany, Hungary, Iceland, Italy, Korea, Luxembourg, Spain and the United States. In total the dataset provides 219 observations for analysis in examination of level estimates and 206 observations for growth estimations. Unarguably this study would benefit from an increase in sample size, something easily said of many studies, however it is worth noting the sample size employed is the same as used by Newhouse (1977) in his highly cited work and other studies such as van Doorslaer et al. (1999) employ smaller sample of OECD countries.

Annual per capita health expenditure standardized in U.S. dollars and adjusted for purchasing power parity by the OECD, is the dependent variable. The dependent is employed in log form and evaluated in level and growth values. The determinants are: base expenditure in the first year, per capita income proxied by the logarithm of the real per capita gross domestic product (GDP) standardized in U.S. dollars for all countries, MRI per million, proportion of age 65 and older, country specific health system factors, and time period indicators. Country specific health system factors are dummy indicators denoting if a country is: a public reimbursement system (*Australia, Czech Republic -1997 forward, France, Luxembourg, and the U.S.*), a public integrated system (*Finland, Iceland, Italy, and Spain*), or involved in gate keeping (*Canada, Czech Republic, Germany, Hungary, Iceland, Italy, and Spain*).

The variables we employ, excluding MRI, are customary for health expenditure studies. The variable base is the initial amount of expenditure in the first year, providing a reference of each nation's initial state. The time period indicator is reported in increments of five years with (1990-1994) as the reference period. Other periods of time such as annual or decade were considered, with five year periods providing an indication of expenditure change while maximizing degrees of freedom. The results were generally consistent with the different time indicators examined. Additionally, some values for MRI were obtained from other studies, such as Bell (1996), to fill-in data gaps. Descriptive statistics are provided in table 1.

TABLE 1
DESCRIPTIVE STATISTICS BY FIVE YEAR PERIODS

Variable	Mean	Std. Dev.	Min	Max	Period	Δ Variable	Mean	Std. Dev.	Min	Max
Exp	1463	727	329	3500	**1990-94**	Δ Exp	0.05	0.05	-0.08	0.26
	1822	868	502	4318	**1995-99**		0.05	0.04	-0.07	0.15
	2470	1145	753	6014	**2000-04**		0.07	0.03	-0.01	0.17
	3061	1427	1276	7290	**2005-08**		0.05	0.04	-0.05	0.14
Income	18559	6659	8195	38166	**1990-94**	Δ Income	1.86	3.50	-11.60	9.40
(GDP)	22454	8082	9069	48845	**1995-99**	(Δ GDP)	3.44	2.48	-6.90	9.50
	28345	10656	12265	65006	**2000-04**		3.17	1.80	-0.20	8.50
	34258	14009	17014	79793	**2005-08**		3.64	1.67	0.60	7.50
Tech	2.42	2.65	0.10	11.80	**1990-94**	Δ Tech	0.16	0.16	-0.04	0.67
(MRI)	4.42	3.38	1.00	15.40	**1995-99**	(Δ MRI)	0.11	0.10	-0.04	0.49
	7.81	5.90	1.70	25.60	**2000-04**		0.10	0.15	-0.71	0.59
	10.91	7.00	2.60	26.90	**2005-08**		0.07	0.07	-0.03	0.34
Age	12.70	2.55	5.10	16.30	**1990-94**	Δ Age	0.17	0.10	0.00	0.40
	13.56	2.70	5.90	18.00	**1995-99**		0.16	0.12	-0.10	0.40
	14.24	2.79	7.20	19.30	**2000-04**		0.13	0.16	-0.20	0.60
	14.82	2.90	9.10	20.00	**2005-08**		0.15	0.18	-0.10	0.60
PR	0.31	0.47			**1990-94**	PR	0.31	0.47		
	0.35	0.48			**1995-99**		0.35	0.48		
	0.38	0.49			**2000-04**		0.38	0.49		
	0.38	0.49			**2005-08**		0.38	0.49		
PI	0.23	0.42			**1990-94**	PI	0.23	0.42		
	0.23	0.42			**1995-99**		0.23	0.42		
	0.23	0.42			**2000-04**		0.23	0.42		
	0.23	0.43			**2005-08**		0.23	0.43		
GK	0.54	0.50			**1990-94**	GK	0.54	0.50		
	0.54	0.50			**1995-99**		0.54	0.50		
	0.54	0.50			**2000-04**		0.54	0.50		
	0.54	0.51			**2005-08**		0.54	0.51		

METHODOLOGY

The main objective of this paper is to assess the impact of technology on health care expenditures. The general form of the estimation model is:

$$HC\ Exp = f(B, I, T, A, \boldsymbol{P}, \boldsymbol{L}) \tag{1}$$

Where health care expenditures adjusted for purchasing power parity in U.S. dollars-*HC Exp* is a function of: *B*-base year values, *I*-annual income values, *T*-technology, *A*-population age structure, ***P***-vectors describing health system policy vectors (*public reimbursement, publicly integrated, or gate keeping*), and ***L***- vectors of time which are segmented in periods of five years (lustrums). Employing variables of this type are observed in most expenditure studies, with the exception of technology measurement (Barros, 1998; Livio Di Matteo, 2005; Okunade & Murthy, 2002). Analysis of expenditures is made in level values, as well as in annual growth rate with the base value as the constant. The growth rate equations employ annual rate of change values of expenditure, income, technology, and age; other values are static as dummy indicators. As the growth rate value is obtained as the change from year *t* to year *t+1* relative to year *t*, the growth rate data are less one time period than the level data as growth estimations begin in 1991 and extend to 2007.

A number of previous studies examining health expenditures of OECD countries employ panel models that assume the random effect (RE) estimator as appropriate. Within the RE assumption dummy indicators of time periods and indicators of country specific effect via policy system vectors, denoted in this study as a ***P***-vectors are assumed to control for individual parameters and ***L***-vectors control for time varying parameters. A Hausman test support our use of a RE model with respect to generally employed fixed effects model, refer to Table 2. Under the null hypothesis of the Hausman specification test a difference in the random effects versus fixed effects coefficients not systematic. Therefore, we employ a RE model to observe variables that do not exhibit within subject variation, as these variables are excluded from a fixed effects estimation.

TABLE 2
HAUSMAN TEST RESULTS

	Level	Growth
Chi-squared :	4.86	8.66
Chi-squared Prob. :	0.433	0.124
H_o: difference in coefficients not systematic		

Testing of the Functional Form

Prior research on growth determinants has offered evidence that there is a possibility of misspecification when examining expenditure determinants and employing the typical variables (Barros, 1998; Culyer, 1988; L. Di Matteo & Di Matteo, 1998; Hansen & King, 1996). Ramsey's RESET (Regression equation specification error test) test was employed to test for model misspecification, or rather a missing variable(s). The base model as specified in equation (1) is compared against the base model augmented by the dependent applied in a different form. If model (1) can be significantly improved upon with the inclusion of one or more terms of the modified form, the model is said to be incomplete. The RESET test's null hypothesis of no misspecification cannot be rejected, therefore the base model is consistent in the functional form. This finding differs from previous studies whose equation is augmented with a non-linear component of the dependent variable.

Testing for Endogeneity

Without examination, a plausible argument for endogeneity bias could be made, specifically with respect to income (GDP) and technology (MRI). Testing for variable effects lending to model inconsistency, an instrumental variable test of the error term is employed. We regress a set of instruments specific to each of the variables in question, obtaining a residual vectors μ - a separate residual estimate exists for each variable in question such that there is υ_{MRI} and υ_{GDP}. The instruments employed in estimation of GDP are borrowed from Barros (1998) as the one period lagged level value of GDP, country dummies, and the quantity of health expenditure to GDP at the end of the previous period. The instruments of MRI are the one period lagged level value of MRI, country dummies and the quantity of health expenditure to MRI at the end of the previous period. The residuals are then integrated into a regression of expenditures and reported in Table 3. The reader may refer to Hausman (1978) and Godfrey (1988) for further detail.

As μ is not statistically significant from zero, the null hypothesis of exogeneity cannot be rejected. Therefore with a given level of confidence, we assume endogeneity bias is not observed in the model. While MRI has not been previously examined for endogeneity, an exogenous finding of GDP growth supports the previous report by Barros (1998).

TABLE 3
TESTING FOR ENDOGENEITY IN GDP AND MRI COVARIATES

	Level	P-value	Growth	P-value		Level	P-value	Growth	P-value
Cons.	-1.27407 (2.14)	0.000	0.04768 (3.57)	0.000	Cons.	6.54761 (120.11)	0.000	0.07959 (4.30)	0.000
Base	0.00039 (15.49)	0.000	0.00000 (1.61)	0.108	Base	0.00062 (16.64)	0.000	-0.00001 (2.55)	0.012
GDP	0.82461 (13.33)	0.000	0.00566 (2.18)	0.031	MRI	0.02597 (10.78)	0.000	-0.07546 (0.57)	0.570
μ	0.83898 (0.69)	0.493	-0.00205 (0.61)	0.544	μ	-0.02315 (1.16)	0.248	0.12001 (0.93)	0.351

** t-staistics within ( ) with robust S.E.

RESULTS

Regression estimates shown in table four confirm that technology is a statistically significant level and growth regressor for HC expenditures at the 95% confidence level. The fully specified model is shown in the column labeled (5) explains 90.2 percent of the overall level variance and the growth model explains 17.0 percent. The technology estimates indicate that investment in technology lends to greater per capita health care expenditures (.008) as well as increasing the rate of expenditure growth (.050). The associated marginal effects express how a proportionate change in an independent variable will affect a proportionate change in the dependent variable. As the estimates are scale free, we can determine how a 1%, 10%, or any percentage change of interest will influence a change in the variable of interest. The marginal effects indicate that a one percent increase in technology will increase health expenditure growth by (.104) percent. While statistically significant the amount of variance explained by including the technology variable, model (3) R^2 of (.859), is relatively small in comparison with the income model (2) R^2 of (.867). The contribution is smaller in the growth model. This finding supports the extant literature that posits technology as being a significant driver of health expenditures, though contradicting the magnitude of technology's influence. Although the estimates are statistically significant, technology does not appear to be as large of a driver of health expenditures as previously suggested. At face value this may seem incorrect, however if we consider the assessment process involved in technology adoption, these estimates reasonably apply. In the adoption assessment process we identify the potential technology as more or less costly as the current method and consider the effectiveness relative to the current method (Laupacis, Feeny, Detsky, & Tugwell, 1992). This process results in four potential outcomes for the technology under review, the technology is: 1. less costly and more effective, 2. more costly and more effective, 3. less costly and less effective, 4. more costly and less effective. Within this process, outcomes one and two receive consideration, with outcome three possibly receiving consideration where conditions that target expenditure reduction or capital constraints allow for less effective technology with sensible savings. Technologies that fall under outcomes one and two result in increasing costs and decreasing costs, thus some technologies that increase expenditure are partially offset by expenditure reducing technologies, thus it is plausible to consider that costs are not deeply driven by technology as previously conceived.

TABLE 4
REGRESSION ESTIMATES WITH ROBUST STANDARD ERRORS

	Level Estimates						Growth Estimates				
	(1)	(2)	(3)	(4)	(5)		(1)	(2)	(3)	(4)	(5)
Cons.	6.510	-5.344	-4.228	-4.101	-3.802	Cons.	0.048	0.036	0.032	0.055	0.055
	(65.44)	(19.55)	(10.67)	(11.85)	(6.36)		(5.10)	(4.93)	(4.05)	(2.40)	(2.50)
Base	0.001	0.000	0.000	0.000	0.000	ΔBase	0.025	0.080	0.030	-0.003	0.006
	(8.99)	(2.73)	(4.00)	(3.82)	(4.00)		(0.22)	(1.08)	(0.39)	(0.03)	(0.05)
Tech	0.051		0.008	0.008	0.008	ΔTech	0.040		0.048	0.045	0.050
	(17.03)		(4.16)	(4.22)	(3.50)		(1.47)		(1.63)	(1.63)	(2.02)
Income		1.257	1.139	1.094	1.060	ΔIncome		0.045	0.005	0.004	0.004
		(50.51)	(30.42)	(28.82)	(16.58)			(3.93)	(3.20)	(2.50)	(2.38)
Age (65+)				0.013	0.016	ΔAge (65+)				-0.001	-0.001
				(1.86)	(2.16)					(0.58)	(0.82)
PR				0.045	0.051	PR				-0.005	-0.005
				(0.96)	(1.05)					(0.44)	(0.44)
PI				-0.011	-0.006	PI				-0.009	-0.009
				(0.12)	(0.07)					(1.12)	(1.09)
GK				0.172	0.162	GK				-0.009	-0.008
				(2.12)	(2.21)					(0.87)	(0.77)
1995-99[1]					-0.316	1995-99[1]					-0.007
					(1.79)						(0.79)
2000-04					-0.002	2000-04					0.018
					(0.08)						(1.97)
2005-07					0.010	2005-07					-0.001
					(0.25)						(0.05)
R^2	0.723	0.859	0.867	0.895	0.902	R^2	0.054	0.090	0.094	0.109	0.170
Obs.	219	219	219	219	219	Obs.	206	206	206	206	206
Marginal Effects											
Base	0.034	0.031	0.034	0.039	0.042	ΔBase	0.031	0.098	0.037	0.004	0.007
Tech	0.042		0.007	0.007	0.006	ΔTech	0.083		0.100	0.093	0.104
Income		1.683	1.522	1.462	1.417	ΔIncome		0.240	0.256	0.228	0.224
Age (65+)				0.023	0.029	ΔAge (65+)				-0.173	-0.284
PR				0.002	0.002	PR				-0.033	-0.033
PI				-0.001	-0.001	PI				-0.040	-0.039
GK				0.012	0.012	GK				-0.096	-0.840
1995-99[1]					-0.001	1995-99[1]					-0.040
2000-04					0.000	2000-04					0.104
2005-07					0.000	2005-07					-0.002

** z-staistics within ( ) [1] 1990-1994 Reference Point

Figure 4 plots expenditure standard deviations over average value, providing a visual representation of convergence for high and low adopters of technology. An indication of convergence is given by a decreasing ratio of standard deviation to average value. High adopters are nations with technology above that average amount level of technology for the population, while low adopters have adoption levels below the average level of technology. Cyclical patterns of convergence are noted in plots of high and low adopters of technology. This would suggest there was an initial delay in adoption for the low group and thus patterns are not synchronous. Specifically, there are first movers and latter adopters of technology, supporting the findings of Slade and Anderson (2001). As well, reinvestment and acquisition of new technology is staggered between high and low adopters. These results confirm the existence of technology convergence as latter adopters attempt to "catch-up" to first adopters when technologies likely become more economical. Not surprisingly this difference in the date of acquisition could lend to diverging expenditures, like purchasing a new car in the beginning of the year versus year end, supporting the findings of Anderson, Reinhardt, Hussey, and Petrosyan (2003). Figure 4a displays patterns of expenditure increase and decrease associated likely associated with technology uptake. Noting the increasing and decreasing expenditure plots of figure 4a are spaced six to seven years apart, complements Bell's report of a 5-7 year technology lifecycle. We can identify a sharp increase in health expenditures of high adopters in 1991, assumed to be technology investment, this pattern of a sharp increase in health expenditures of high adopters is not observed again till 1998, a seven year gap.

FIGURE 4
CONVERGENCE BY MRI ACQUISITION

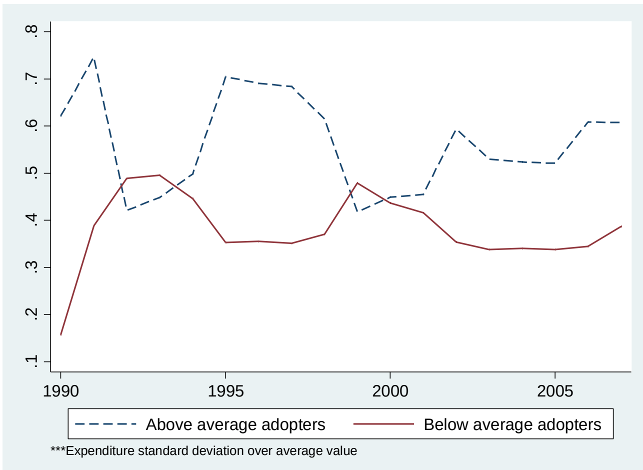
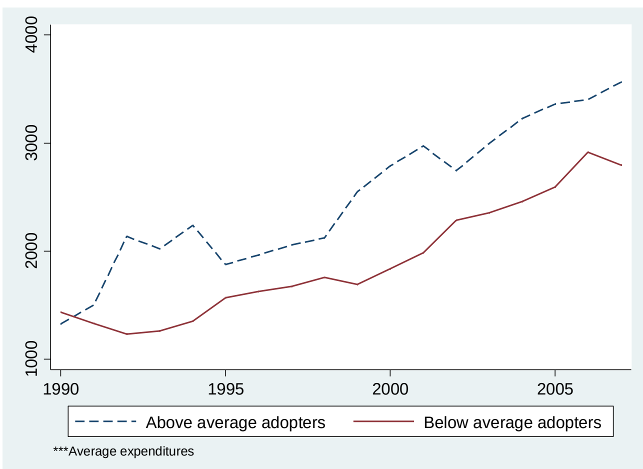


FIGURE 4A
EXPENDITURES BY MRI ACQUISITION



Consistent with previous reports, income is the major determinant of health care expenditure lending to increases in level and growth health expenditures with increasing income. Model (2) explains 85.9

percent of the overall level variance and 9 percent of the growth variance. Income elasticities for level estimates are greater than one, indicating that at the given point of health expenditure, a 1 percent increase in income will on average result in a health expenditure increase greater than 1 percent, 1.417 percent in the fully specified model. As example if income in the US increases from $30,000 to $30,300, a 1 percent increase of $300 in income, holding all else equal-expenditures will expectedly increase from 7500 to 7605, a 1.417 percent increase of $105. In terms of health care expenditure growth, a 1 percent increase in income growth results in an expenditure growth increase of .224 percent.

FIGURE 5
CONVERGENCE BY PUBLIC INTEGRATED

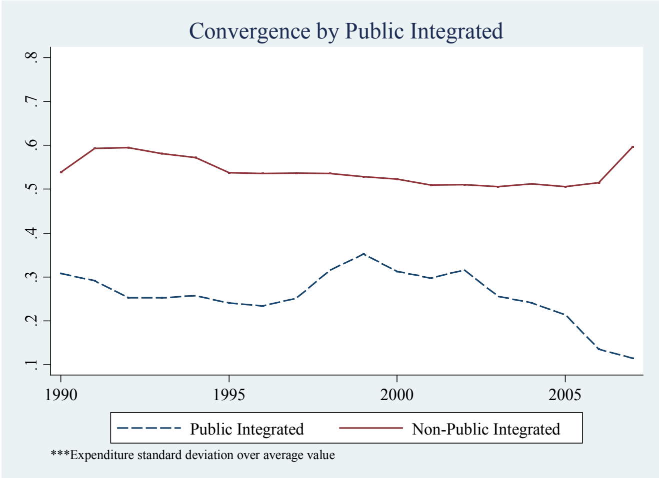
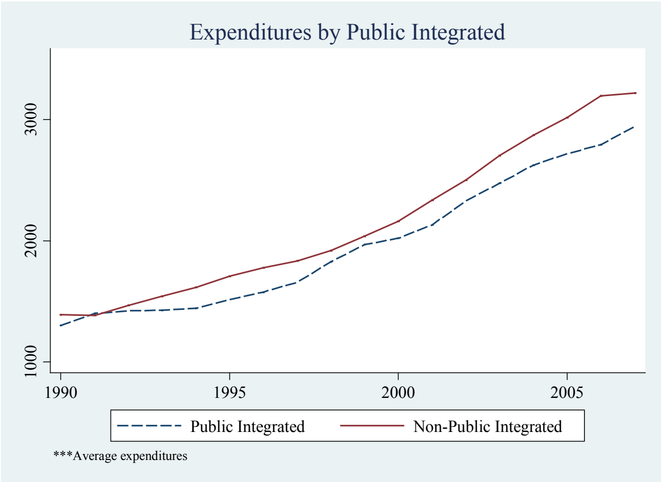


FIGURE 5A
EXPENDITURES BY PUBLIC INTEGRATED



Indicator variables of health system policy, vector P, indicate the average effect on health expenditures by instating policy in the absence of such policy, thus capturing the discrete change of the indicator. Moving to systems of public reimbursement and gate keeping on average will increase expenditures. This finding is similar to the findings of Escarce et al (2001), as they report greater expenditures for gate keepers. Systems that are public integrated tend to have lower expenditures, though statistical significance is not found. Despite the increase in level expenditures brought about by gate keeping and public reimbursement, all of the system variables tend to result in lower expenditure growth. Of the three, the estimates indicate that systems which are public integrated have lower expenditure growth (-0.009) and are more consistent in reducing expenditure growth, sig. of (1.09) versus (0.44) and (0.77). Similarly, Delnoij et al. (2000) and Greβ et al. (2004) report that expenditure growth is reduce with an uptake of gate keeping.

FIGURE 6
CONVERGENCE BY PUBLIC REIMBURSEMENT

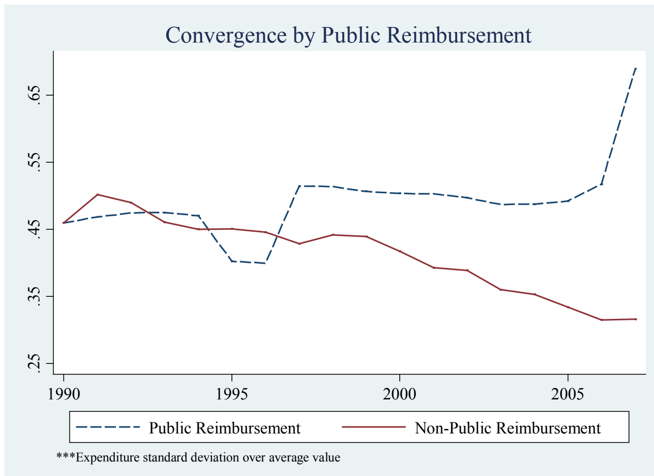
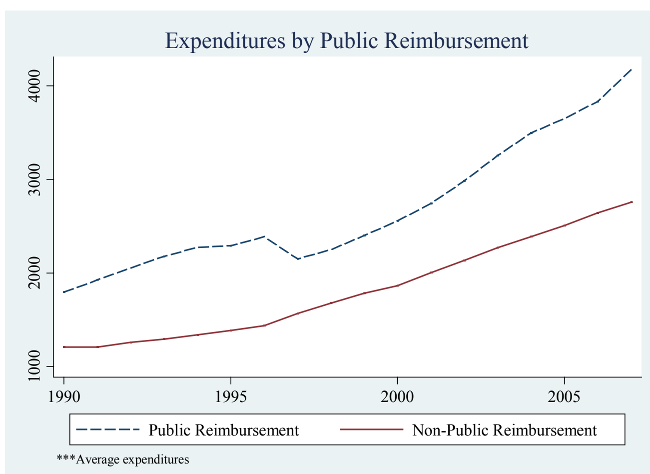


FIGURE 6A
EXPENDITURES BY PUBLIC REIMBURSEMENT



Comparative plots of health systems for integrated systems can be visualized in figure 5a and for gate keeping in figure 7a. Despite the negative growth coefficients for public reimbursement, data plots (figure 6a) indicate that systems with public reimbursement mechanisms tend to have higher per capita expenditures and that the expenditure gap between adopters and non-adopters is growing. Systems that are public integrated tend to have lower expenditures by way of visual interpretation of figure 5a, as well as lower expenditure growth. Figure 5 reveals that countries adopting such systems tend to have similar per capita health expenditures, whereas non-adopters are more greatly varied. This is consistent with the regression findings and is likely the result of expenditure targeting policies that occur when the system is public integrated. However, with public reimbursement there is increased variance in health expenditures across the nations, refer to figure 5. These results further suggest that expenditure control is more effective when the system is public integrated as there is lower variance across the adopter group with lower per capita costs, rather than higher costs that on average occur with public reimbursement. Additionally, the growth coefficient for public integrated systems (-.009) results in lower expenditure growth than public reimbursement (-.005).

FIGURE 7
CONVERGENCE BY GATE KEEPING

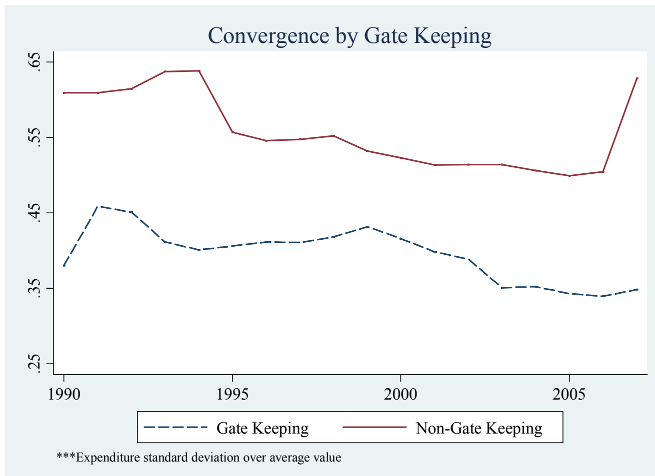
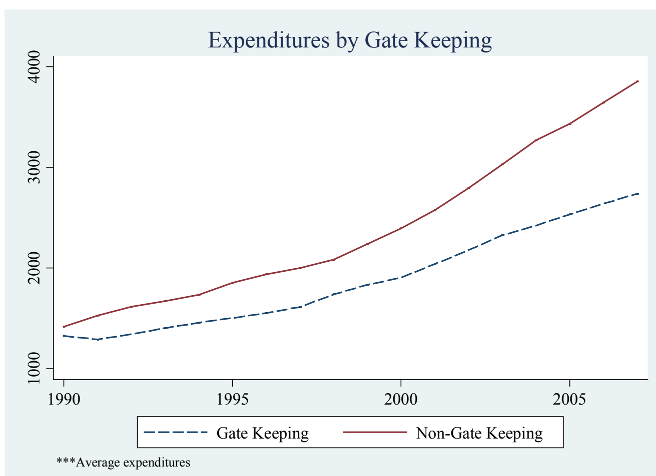


FIGURE 7A
EXPENDITURES BY GATE KEEPING



The population structure (age 65+) is associated with greater level expenditures, as a 1 percent increase in the proportion of age 65 and older population older would increase per capita expenditures by .029%. This result is not surprising at all and is consistent with the previous literature. Growth estimates of population structure reveal that an older population is associated with lower expenditure growth. This may seem counterintuitive, however this is a plausible outcome. A majority of individuals age 65 or older are retired and tend have low income if not stationary income growth, “fixed income”. It is possible that this variable is capturing the ability of this group to consume health goods and services relative to younger individuals having greater abilities to consume. Though, the simple explanation is that the estimate closely approaches zero (-0.001) and lacks statistical significance.

Data plots of the age 65+ variable, referring to figures 8 and 8a, contradict the regression results. Figure 8a plots those nations having a lower proportion age 65+ as incurring higher per capita health expenditures. Figure 8 reveals that there is a greater amount of expenditure variability among younger populations, suggesting that the regression is capturing the influence of increasing age on expenditures, not observed in the data plots. This can occur when a few observations shift the group plot and would expectedly be associated with a greater group standard deviation as observed in figure 8.

FIGURE 8
CONVERGENCE BY AGE STRUCTURE

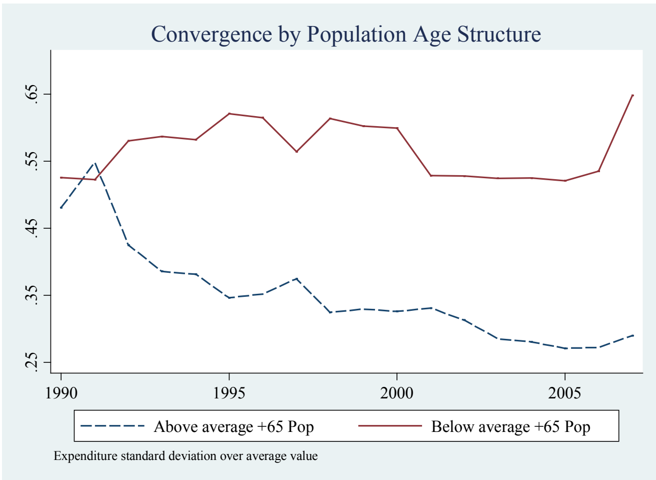
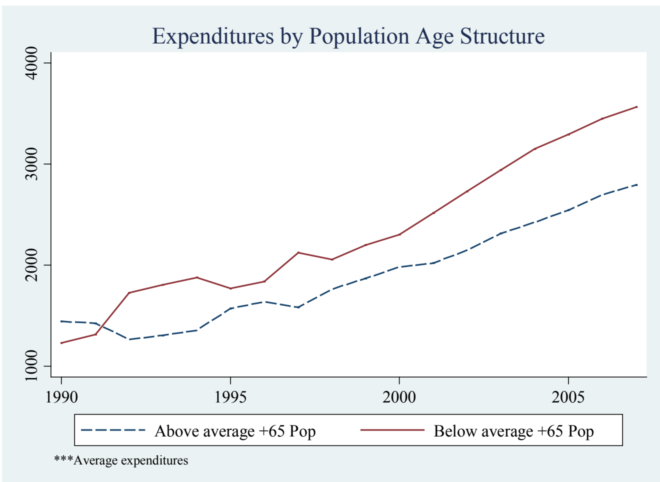


FIGURE 8A
EXPENDITURES BY AGE STRUCTURE



Estimates of base year expenditures from 1990 are positive in level and growth models, indicating that nations with greater expenditures in the base year tend to maintain greater expenditures throughout the sample period. In figure 2, most nations maintain their high level of expenditures throughout the study with the exception of Luxembourg. This finding suggests that nations with larger per capita expenditures will continue having relatively excessive expenditures without policy intervention as only changes in policy or proportion of the age 65+ population result in declining expenditure growth.

The time index captures the period trend in expenditures over time series with respect to the reference year and controls for any non-linearities within the data that may occur. Expenditure growth is noted as significantly increasing in 2000-2004. During this period there is notable expenditure growth for the U.S. and Luxembourg (refer to figure 1). The results overall suggest that most nations within the study are effectively attempting to reduce health expenditure growth as there are downward trends in the other two periods relative to the reference period. Additionally, different time periods were employed to capture changing effects with results maintaining consistency.

CONCLUSION

In this study, determinants of international health care expenditures explain a large amount of the observed level variation (90%+). This study uniquely contributes to the existing literature in the following ways. A proxy for technology, magnetic resonance imaging units, is applied to estimate the effect of technology, rather than assuming technology as the unexplainable portion of a model. Contrasting with previous research examining international health expenditures, the influential effect of technology is noted as having less of an effect than previously suspected. Third, expenditure determinants are examined for convergence/divergence influences. Technology is found to have a cyclical pattern of convergence that is likely the result of delayed technology adoption and, or reinvestment at the end of a technology's useful life. Systems that are public integrated appear to be more adept with cost control versus public reimbursement systems or gate keeping processes, as per capita expenditures tend to be lower and converge with a much lower variation. Lastly, evidence of a long-run stable relationship between expenditure and MRI (technology) is provided the appendix.

Additional findings from this study reveal that determinants of expenditure may exhibit dissimilar influences when modeled in level versus growth form, indicating that a determinant may increase expenditures while slowing future expenditure growth. Gate keeping and public reimbursement are policies increase expenditures in level estimates, but also lend in reducing expenditure growth. Increasing income and technology will contribute to increasing expenditures in level and growth models.

Comparing level and growth estimates provides evidence of increasing expenditures with overall reductions in expenditure growth, indicating effective expenditure control is at work for most of the sample as there is a downward trend in expenditure growth relative to the initial period of the time series. The estimates suggest that each nation's expenditures tend to differ mostly by income effects. Therefore developing nations that tend to have greater income growth should likely face the largest amount of expenditure growth, and as a result converging towards nations with lower expenditure growth rates. However, these results show that nations with larger expenditures in the base year continue to have larger per capita expenditures overall. The growth estimates indicate that nations with larger per capita expenditures will in general continue having relatively excessive expenditures without effective policy intervention.

In summary, the findings show that technology is a significant component to consider in estimating health care expenditures, but much less influential on health expenditures than previously postulated. The majority empirical results presented are consistent with prior studies examining per capita expenditures, though again, this study extends the literature with technology estimation and examination of convergence/divergence. However, contrary to most of the extant literature, this study finds more evidence pointing towards overall health care expenditure divergence instead of convergence, signifying a strong need for further expenditure research and effective policy intervention.

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APPENDIX

Stationarity & Cointegration

To confirm the veracity of this study’s findings, stationarity and cointegration are tested. While not the principle goal of this study the results provide further evidence in support of MRI. Results from panel unit root tests, refer to table A-1, indicate the variables have unit roots in level form and none when differenced. This is as expected and is similar in finding with Okunade and Murthy (2002).

Due to limited and unbalanced sample, we employ Westerlund’s cointegration tests. Westerlund’s method was employed as it is reported as being robust under these conditions (Persyn & Westerlund, 2008; Westerlund, 2007). Additionally, other tests such as Johansen's maximum likelihood cannot be used due to sample constraints. Referring to table A-2, the null test is one that the panels are not cointegrated. Cointegration is strongly supported for growth values as well as level values. As a control, cointegration of GDP and expenditures was performed, with similar results obtained. As McCosey and Selden (1998) and Okunade and Murthy (2002) show GDP as having a unit root and is cointegrated with health expenditures, the conclusion is that technology is cointegrated with expenditures.

TABLE A-1
PANEL UNIT ROOT TESTS

	Im-Pesarn-Shin		ADF		Phillips-Perron	
	Stat. (lag)	P-Value	Stat. (lag)	P-Value	Stat. (lag)	P-Value
EXP	6.615 (1)	1.000	-1.924 (1)	0.973	-2.485 (1)	0.994
GDP	4.932 (2)	1.000	-0.229 (1)	0.591	-1.598 (1)	0.945
MRI	3.408 (1)	1.000	-1.307 (1)	0.905	-0.837 (1)	0.799
AGE	1.862 (1)	0.969	-2.355 (1)	0.991	-1.218 (1)	0.889
Δ EXP	-3.197 (1)	0.001	4.313 (0)	0.000	4.015 (0)	0.000
Δ GDP	-3.576 (1)	0.000	7.190 (0)	0.000	5.671 (0)	0.000
Δ MRI	-3.576 (0)	0.000	10.227 (0)	0.000	9.859 (0)	0.000
Ho: All panels contain unit roots						

TABLE A-2
WESTERLUND'S COINTEGRATION TESTS OF EXP = MRI

	Level values			Δ Values		
Statistic	Value	Z-value	P-value	Value	Z-value	P-value
Gt	-3.491	-5.095	0.000	-4.150	-7.737	0.000
Ga	-20.730	-4.787	0.000	-16.199	-2.240	0.013
Pt	-9.866	-2.618	0.004	-14.098	-7.896	0.000
Pa	-16.500	-4.555	0.000	-15.038	-3.529	0.000

H_o: Panels are not cointegrated